National Park Service
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Sierra Nevada Network

Vital Signs Monitoring Plan
Phase III Draft Report

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EXECUTIVE SUMMARY

Chapter 1: Introduction and Background

The Sierra Nevada Network (SIEN), named after the mountain range in which these parks are located, comprises four park units

- Devils Postpile National Monument
- Kings Canyon National Park
- Sequoia National Park
- Yosemite National Park

Collectively, these four park units contain 657,980 hectares—89 percent of which is designated Wilderness. Sequoia and Kings Canyon National Parks share a common border and are administered and managed jointly under one superintendent.

The mission of the Sierra Nevada Network is to develop and implement ecological monitoring under the National park Services' Vital Signs Monitoring program. This Phase III Report is the initial draft Monitoring Plan for SIEN; it contains updated material from the Phase I (FY2004) and Phase II (FY2005) documents, including seven new chapters (chapters 4–10, described below). This report will be peer reviewed by WASO staff and collaborators in the next few months, modified as a result of these reviews, and submitted for final peer review in December 2007.

The focus of the SIEN program will be to monitor ecosystems and biotic elements to detect long-term change in ecological condition. The most significant stressors affecting Sierra Nevada ecosystems are: 1) altered fire regimes; 2) non-native invasive species; 3) air pollution; 4) habitat fragmentation; and 5) rapid anthropogenic climatic change. Many additional, more localized, stressors present significant management issues. These are summarized in this monitoring plan.

Because of the critical importance of Sierra Nevada water resources (both within our Network and to the region), the potential for climate change to alter hydrologic processes, and the national NPS Water Resources Division program to establish water quality monitoring in all networks, SIEN has placed particular emphasis on summarizing and evaluating existing information on water resources. Water quality monitoring is fully integrated within the SIEN monitoring program.

Chapter 2: Conceptual Models

SIEN has developed conceptual models to guide the development of the monitoring program. We use overview models to 1) highlight the ecosystem factors that interact with processes to structure the physical environment and its biotic communities; 2) illustrate inputs and outputs that affect the Sierra Nevada landscapes; 3) emphasize the most important stressors for the Sierra Nevada and their interactions; and 4) highlight the focal systems and processes we target for monitoring. More specific, detailed conceptual models focus on our vital signs (see below).

Chapter 3: Vital Signs

SIEN provides a list of 33 vital signs, representing a balance of ecosystem driving variables (e.g., weather, climate) and response variables (communities and species). These vital signs provide a focus for monitoring at different spatial and temporal scales, and they represent a mix of sensitive and early indicators with slower responding, integrative indicators. Although we realize it will not be possible to monitor all of these vital signs in the immediate future, they do represent a powerful and balanced guide for developing an integrated long term monitoring program. We have identified 12 vital signs (*tier 1 implementation list*) for which monitoring is planned in the near future. Because funds are limited, we hope to achieve monitoring for this subgroup through co-location and integration.

Chapter 4: Sampling Design

The costs, benefits, and tradeoffs of sampling–particularly in SIEN ecosystems–are described in Chapter 4. We present draft statistical sampling designs for protocols the network is developing, including a description of co-location and integration. Because of our extensive and logistically-challenging landscapes, the use of index (judgment based) and survey (random, spatially balanced) sites will be used by SIEN for many vital signs.

Chapter 5: Monitoring Protocols

Protocol Development Summaries for 12 vital signs appear in Appendix __. Each summary explains the reasons why the vital sign was selected as a surrogate representing ecosystem condition, our monitoring objectives, and describes our general approach for monitoring protocol development. SIEN has created workgroups (for each protocol) whose purpose is to refine vital signs monitoring objectives, develop opportunities and methods for integration; workgroups are composed of SIEN, SEKI, YOSE, and USGS-BRD staff.

Chapter 6: Data management

The Data Management Plan for the Sierra Nevada Network (now in draft), serves as the overarching strategy for ensuring data collected by the Inventory & Monitoring program are subjected to rigorous quality assurance and control procedures, and that data and information are made available to others for decision making, research, and education. SIEN's Plan is *unique* in NPS: it has been developed to include detailed strategies for data and information management for its individual park resources management programs as well.

Chapter 7: Data Analysis and Reporting

As part of the Inventory & Monitoring Program, the National Park Service is committed to promoting the conduct of high quality projects in national parks. An essential element of any science or research program is peer review, thus schedules for peer review of SIEN proposals, study plans, and monitoring protocols are described. As part of its monitoring program, SIEN will ensure data are regularly analyzed, interpreted, and reported to park managers and interested parties. Further, these data will be made available in formats appropriate for each audience (e.g., park managers, scientists, students and interested public). While described in general terms infra, a more detailed discussion of data analyses will be included in SIEN's final Monitoring Plan (FY2007).

Chapter 8: Administration and Implementation of the Monitoring Program

This chapter describes our plan for administering the SIEN monitoring program, including integration with individual park operations and other key partnerships (e.g., USGS). It describes a discussion of the SIEN Board of Directors, our Science Committee, and current and future roles (FY2007–F2011) in development of our Network monitoring program.

We present a staffing plan to accomplish implementation of monitoring (FY2007–FY2010). The Network will have a three-year transition period (FY 2008-2010), during which monitoring of nine vital signs (water chemistry, amphibians, weather/climate, landscape mosaics, fire regimes, snowpack, wetland plant communities, wetland water dynamics, wetland invertebrates) is currently planned. During the same period, protocol development will continue for remaining vital signs; however, recent (December 2006) Board discussions may result in changes which alter this schedule. Finally, a discussion of the Network's 10-year program review is provided.

Chapter 9: Schedule

A schedule for development, peer review, and implementation of each monitoring protocol (and composite vital signs) is provided. The network is developing eight protocols that encompass 13 vital signs over the next four years.

Chapter 10: Budget

In this chapter we present the budget for the SIEN monitoring program during year one of operation–2008 (i.e., after review/approval of our plan), and we present an estimated 5-year projected budget.

Annually, SIEN receives $657,900 from the National Park Service Servicewide Inventory & Monitoring Vital Signs program and $61,500 from the NPS Water Resources Division for water quality monitoring. We consider the years 2008-2010 "transition years" in which we will have network staff devoted to complete protocol development as well as Data Management Plan implementation. During 2008-2010, we anticipate allocating approximately 65% of the budget to core network Personnel; this amount is reduced to about 55% by 2011-2012, after which time protocols are expected to be developed and in implementation.

ACKNOWLEDGMENTS

The Sierra Nevada Network's (SIEN's) Phase III Vital Signs Monitoring Plan could not have been completed without the commitment, hard work, and generosity of many people.

We thank the SIEN Science Committee members, who contributed substantial effort toward protocol development for high-priority vital signs. Park and USGS Science Committee members include: Lisa Acree, Athena Demetry, David Graber, Steve Thompson and Harold Werner (all NPS), and Nate Stephenson and Jan van Wagtendonk (USGS-Western Ecological Research Center). We thank those who served as protocol work group leads: Athena Demetry, Bill Kuhn, Steve Thompson, and Harold Werner, as well as the numerous park and USGS staff members and outside cooperators who participated on protocol work groups.

Other contributions to the draft Phase III vital signs monitoring plan include conceptual model development, writing appendices, contributing sections and editing to some monitoring plan chapters, acquiring and preparing images, and doing GIS maps. We thank the following Sierra Nevada staff or cooperators for their contributions: Tony Caprio, Laura Clor, Athena Demetry, Annie Esperanza, Sandy Graban, Sylvia Haultain, Bill Kuhn, Scott Martens, Tani Meadows, Barbara Moristch, Peter Rowlands, Sarah Stock, Steve Thompson, Liz van Mantgem, and Harold Werner. In addition, Justin Hofman was the artist who did a couple illustrations in chapters 1 and 2.

We thank Data Management Plan co-author Pat Lineback (Sequoia & Kings Canyon GIS Coordinator) and Leona Svancara (Upper Columbia Basin Network-UCBN- Data Manager) for their contributions to SIEN's Data Management Plan (DMP). The Data Steering Team members and other data work groups provided park-specific information and feedback during the development of portions of the draft Data Management Plan. Additional people who made significant contributions to the DMP this year include: Bob Basham, Anne Birkholz, Ginger Bradshaw, Ward Eldredge, Paul Gallez, Ann Pfaff, and Dan Sohn. WASO Data Manager Margaret Beer also provided helpful guidance.

Staff from other networks contributed valuable assistance, ideas, and collaboration that facilitated our Phase III report completion and aspects of protocol development. We adapted ideas from several other networks in chapters 4-10, and we acknowledge those networks in the relevant chapters. Lisa Garrett (UCBN Coordinator) and Tom Rodhouse (UCBN Ecologist) coordinated a task agreement to establish shared statistical support for four networks. Statistician Leigh Ann Harrod and Kirk Steinhorst provided statistical consultation for aspects of this monitoring plan and our in-progress protocols. Tom Rodhouse shared useful drafts of chapter 4 (sample design) and reference materials as a starting point for SIEN's chapter 4. Rocky Mountain Network staff (especially Coordinator Mike Britten and Quantitative Ecologist Billy Schweiger) shared ideas and collaborators with SIEN in initiating development of a wetlands/meadow monitoring protocol.

We thank our Board of Directors for providing guidance in planning and program direction and for support of our I&M program in SIEN parks and in the Pacific West Region:

Board of Directors

- Craig Axtell, Superintendent, Sequoia & Kings Canyon National Parks
- Kevin Cann, Deputy Superintendent, Yosemite National Park
- Deanna Dulen, Superintendent, Devils Postpile National Monument
- David Graber, Ph.D., Chief Regional Scientist-Pacific West Region/Sequoia and Kings Canyon National Parks
- Penny Latham, Ph.D., I&M Coordinator, Pacific West Region
- Patty Neubacher, Deputy Regional Director, Pacific West Region
- Niki Nicholas, Ph.D., Chair of Board, Chief, Science and Resources Management, Yosemite National Park
- Peter Rowlands, Ph.D., Chief, Division of Natural Resources, Sequoia & Kings Canyon National Parks
- Mike Tollefson, Superintendent, Yosemite National Park
- Russ Wilson, Deputy Superintendent, Sequoia & Kings Canyon National Parks

Finally, we thank the NPS monitoring program coordinator Steve Fancy, for his tireless support of the program at the national level.

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PREFACE

This document includes the draft final phase of a long-term monitoring plan for four National Park Service (NPS) units in the Sierra Nevada of central California: Devils Postpile National Monument, Sequoia and Kings Canyon National Parks, and Yosemite National Park. Together these parks form the Sierra Nevada Network (SIEN), which the NPS created for the purpose of establishing and implementing an ecological inventory and monitoring program. Development of large-scale monitoring programs to be carried out over long periods of time requires an investment in strategic planning over several years. Establishment of the monitoring portion of the SIEN program is directed by national-level guidance. The monitoring plan for each of the 32 Inventory & Monitoring (I&M) networks around the country is written in three phases, corresponding to the phases of program development, over a period of roughly three to four years.

The Phase I report includes Chapter 1 (Introduction and Background) and Chapter 2 (Conceptual Models) of the monitoring plan. This report described the park resources and management issues, described existing natural resource monitoring and defined general monitoring objectives. The Phase II report builds on the Phase I report by adding Chapter 3, which provides a list of vital signs the network has selected and describes the prioritization process. Finally, the Phase III report provides the implementation and staffing plans for the network's vital signs monitoring program.

This document is the draft Phase III report for the Sierra Nevada Network (SIEN).

Chapter 1 INTRODUCTION AND BACKGROUND

"The misson of the National Park Service is to promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purposes of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

—National Park Service Organic Act 1916

"When I first enjoyed this superb view, one glowing April day, from the summit of the Pacheco Pass, the Central Valley, but little trampled or plowed as yet, was one furred, rich sheet of golden compositæ, and the luminous wall of the mountains shone in all its glory. Then it seemed to me the Sierra should be called not the Nevada, or Snowy Range, but the Range of Light."

—John Muir, "The Mountains of California" 1894

1.1 Purpose

The purpose of the Sierra Nevada Network Inventory & Monitoring Program is to develop and provide scientifically sound information on the current status and long term trends in the composition, structure, and function of park ecosystems, and to determine how well current management practices are sustaining those ecosystems.

To be effective, the monitoring program must be relevant to current management issues as well as anticipate future issues based on current and potential threats to park resources. Natural resource monitoring–in conjunction with inventories, management, and research–provides the information needed for effective, science-based decision-making and resource protection through adaptive management. Adaptive management is a systematic process for continually improving management practices and policies by applying scientific knowledge, principles, and methods to improve resource management

Use of monitoring information provided by our program will increase confidence in management decision-making and improve our ability to manage park resources, mitigate threats to the park, and operate more effectively.

Our program is scientifically credible, will produce data of known quality that are accessible to managers and researchers in a timely manner, and will be linked explicitly to management decision-making processes.

1.2 Legislation, Policy, and Guidance

United States Federal law and National Park Service policies direct national park managers to know the status and trends in the condition of natural resources under their stewardship. When it amended the Organic Act in 1978, Congress strengthened the protective function of the National Park Service (NPS) and provided language important to recent decisions about resource impairment.

The Organic Act states that

> *"the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established…."*

More recently, the National Parks Omnibus Management Act of 1998 established the framework for fully integrating natural resource monitoring and other science activities into the management processes of the National Park System. This Act charges the Secretary of the Interior to

> "*continually improve the ability of the National Park Service to provide state-of-the-art management, protection, and interpretation of and research on the resources of the National Park System*", and to *"… assure the full and proper utilization of the results of scientific studies for park management decisions*." Section 5934 of the Act requires the Secretary of the Interior to develop a program of "*inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources*."

On August 12, 1999, the National Park Service announced a major effort to substantially improve how the NPS manages the natural resources under its care. The Natural Resource Challenge (NRC) is the National Park Service's action plan for preserving natural resources, and it addresses the challenges of caring for our country's natural heritage within the complexities of today's modern landscapes. The NRC calls for substantially increasing the role of science in decision-making, revitalizing and expanding natural resource programs, gathering baseline data on resource conditions, strengthening partnerships with the scientific community, and sharing knowledge with educational institutions and the public.

Congress reinforced the message of the National Parks Omnibus Management Act of 1998 in its text of the FY 2000 Appropriations bill

> *"The Committee applauds the Service for recognizing that the preservation of the diverse natural elements and the great scenic beauty of America's national parks and other units should be as high a priority in the Service as providing visitor services. A major part of protecting those resources is knowing what they are, where they are, how they interact with their environment and what condition they are in. This involves a serious commitment from the leadership of the National Park Service to insist that the superintendents carry out a systematic, consistent, professional inventory and monitoring program, along with other scientific activities, that is regularly updated to ensure that the Service makes sound resource decisions based on sound scientific data."*

In 2001, NPS Management Policies updated previous policy and specifically directed the NPS to inventory and monitor natural systems

> *"Natural systems in the National Park system, and the human influences upon them, will be monitored to detect change. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions."*

Further, *"The Service will*

- *Identify, acquire, and interpret needed inventory, monitoring, and research, including applicable traditional knowledge, to obtain information and data that will help park managers accomplish park management objectives provided for in law and planning documents*
- *Define, assemble, and synthesize comprehensive baseline inventory data describing the natural resources under its stewardship, and identify the processes that influence those resources*
- *Use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals*
- *Analyze the resulting information to detect or predict changes, including interrelationships with visitor carrying capacities, that may require management intervention, and to provide reference points for comparison with other environments and time frames*
- *Use the resulting information to maintain-and, where necessary, restore-the integrity of natural systems"*

Additional statutes provide legal direction for expending funds to determine the condition of natural resources in parks and specifically guide the natural resource management of Network parks, including

- Taylor Grazing Act 1934
- Fish and Wildlife Coordination Acts, 1958 and 1980
- Wilderness Act 1964
- National Historic Preservation Act 1966
- National Environmental Policy Act of 1969
- Clean Water Act 1972, amended 1977, 1987
- Endangered Species Act 1973, amended 1982
- Migratory Bird Treaty Act, 1974
- Forest and Rangeland Renewable Resources Planning Acts of 1974 and 1976
- Mining in the Parks Act 1976
- American Indian Religious Freedom Act 1978
- Archaeological Resources Protection Act 1979
- Federal Cave Resources Protection Act 1988
- Clean Air Act, amended 1990

The Government Performance and Review Act of 1993 (GPRA) mandates that all federal agencies use Performance Management (i.e., measurable, results-oriented, goal-driven planning and management) to accomplish their missions. To implement this management system, the Results Act requires all agencies to develop long-range Strategic Plans, Annual Performance Plans, and Annual Performance Reports. In addition to the national strategic goals, each park has a five-year plan that includes specific park GPRA goals (Table 1-1). Many of these park-specific goals are directly related to natural resources inventory and monitoring needs. In FY2004, land health goals relating to the condition of wetlands, riparian areas, upland areas, marine and coastal areas, and mined lands were added to national level strategic goals.

Table 1-1. Government Performance and Review Act (GPRA) goals for Sierra Nevada Network parks that relate to natural resource condition. (Closely associated park-specific goals are those that relate to the corresponding national-level goals, but use park-specific measures.)

GPRA Goal	Goal Number	Parks with this goal
Resources maintained	Ia	DEPO, SEKI, YOSE
Disturbed lands restored	Ia1A	DEPO, SEKI, YOSE
Disturbed lands restored—fire regime restored	Ia01A	SEKI
Closely associated park-specific land health goal-wetlands	Ia01C	SEKI, YOSE
Closely associated park-specific land health goal-riparian	Ia01D	SEKI, YOSE
Closely associated park-specific land health goal-uplands --includes caves (SEKI) --includes fire regime (YOSE)	Ia01E	SEKI, YOSE
Wilderness character objectives met	Ia10	SEKI, YOSE
Exotic vegetation contained	Ia1B	DEPO, SEKI, YOSE
Improving federal T&E species or species of concern have improved status	Ia2A, Ia02A	SEKI, YOSE
Species of concern populations have improved status	Ia2B, Ia02B	SEKI, YOSE
Invasive animal species controlled	Ia2C	SEKI, YOSE
Air quality in Class I parks does not degrade	Ia3	SEKI, YOSE
Surface water quality- rivers and streams- does not degrade.	Ia4A	SEKI, YOSE
Surface water quality-lakes, reservoirs- does not degrade.	Ia4B	SEKI, YOSE
Ground water quality- maintained	Ia4C	YOSE
Natural resource datasets acquired or developed	Ib01	DEPO, SEKI
Vital signs identified	Ib3A	DEPO, SEKI, YOSE
Vital signs monitored	Ib3B	DEPO, SEKI, YOSE
Special Management Areas: Wild and Scenic Rivers	Ib4B	SEKI, YOSE
Visitor Understanding and Appreciation (of park resources)	IIb1	DEPO, SEKI, YOSE

1.3 Justification for Integrated Natural Resource Monitoring

Knowing the condition of natural resources in its national parks is fundamental to the NPS's ability to manage park resources. National park managers are confronted with increasingly complex and challenging issues that require a broad-based understanding of the status and trends of park resources. For years, managers and scientists have sought a way to characterize and determine trends in the condition of parks and other protected areas. Managers need to assess the efficacy of management practices and restoration efforts, and they need to provide early warning of impending threats. Since most parks are open systems, the challenge of protecting and managing a park's natural resources hinges on a partnership-based, ecosystem-wide approach. Threats, such as air and water pollution or invasive species, often originate outside of a park's boundaries. In these cases, understanding and managing resources may require a regional, national, or international effort.

The NPS needs an ecosystem approach because no single spatial or temporal scale is appropriate for all system components and processes. The appropriate scale for understanding and effectively managing a resource might be at the population, species, community, or landscape level. National parks are part of larger ecosystems and must be managed in that context.

Understanding the dynamic nature of park ecosystems and the consequences of human activities is necessary for management decision-making intended to maintain, enhance, or restore the ecological integrity of park ecosystems, while avoiding, minimizing, and mitigating ecological threats to these systems (Roman and Barrett 1999). Natural resource monitoring provides site-specific information needed to identify *meaningful changes* in complex, variable, and imperfectly understood natural systems. The information we obtain from monitoring may also be useful in determining what constitutes impairment and in identifying the need to initiate or change management practices.

In highly altered environments where natural physical and biological processes no longer predominate (e.g., control of fires and floods in developed areas), information obtained through monitoring can help managers develop effective approaches to restoration, and where restoration is impossible, ecologically sound management.

1.4 The National Park Service Inventory and Monitoring Program Approach and Strategy

Ecological monitoring is now a central component of natural resource stewardship in the NPS, and along with natural resource inventories and research, provides information needed for effective, science-based decision-making and resource protection (Figure 1-1). The strategy of the NPS Inventory and Monitoring Program consists of a framework of three major components

- Completion of 12 resource inventories upon which monitoring efforts can be based
- Eleven experimental or "prototype" long-term ecological monitoring (LTEM) programs
- Monitoring of "vital signs" by 32 Inventory and Monitoring networks

Each network consists of a group of parks linked by shared natural resource and geographic characteristics. The 32 Networks contain approximately 270 parks. The Sierra

Nevada Network (SIEN) is one of the 32 networks included in the service-wide Inventory and Monitoring program and is one of eight networks in the Pacific West Region of NPS.

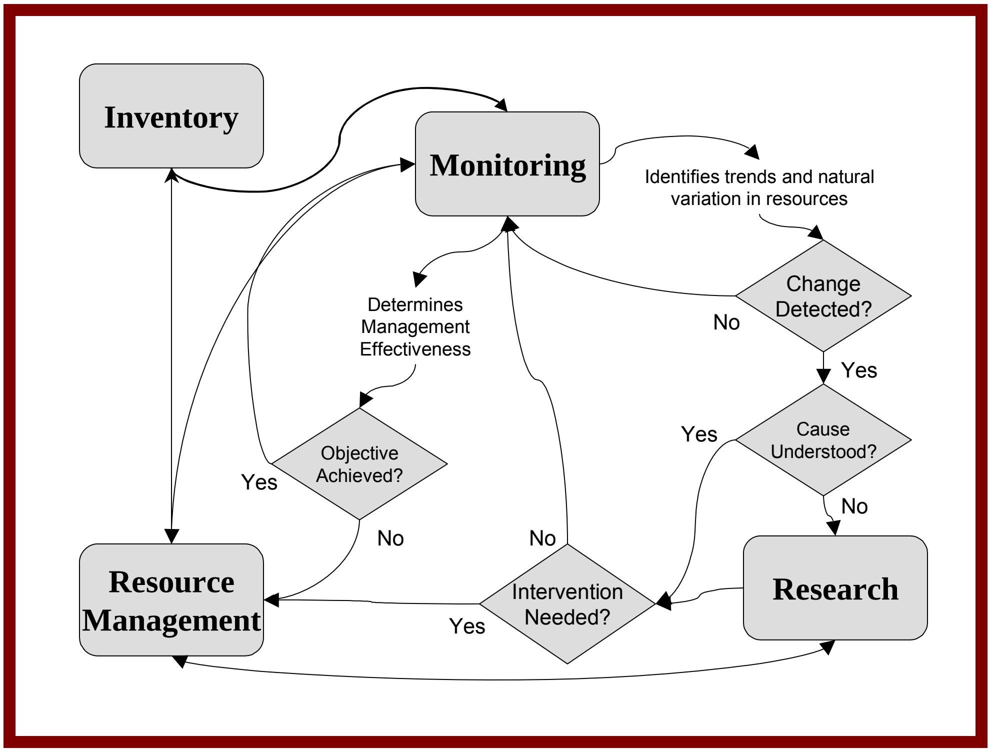


Figure 1-1. Relationships between monitoring, inventories, research, and natural resource management activities in National parks (modified from Jenkins *et al*. 2002).

1.5 Sierra Nevada Network Parks

John Muir was an early wilderness advocate and proponent of the National Park System, inspired by his explorations and wanderings in 'the Range of Light'. A century after his time in the Sierra Nevada, his passion for this mountain range lives on in the many people who visit Sierra Nevada parks each year. In 2004, the Sierra Nevada Network (SIEN) parks had 5,089,750 visitors (Table 1-2), a reflection of the attraction that the diverse and spectacular resources of the Sierra Nevada have for people from around the world. This attraction is also a challenge for park managers who must balance visitor enjoyment and resource protection. This requires systematic inventory and monitoring of park resources.

In establishing a service-wide natural resources inventory and monitoring program, the National Park Service (NPS) created networks of parks that are linked by geography and shared natural resource characteristics. Working within networks improves the efficiency of inventory and monitoring because parks are able to share budgets, staffing, and other resources to plan and implement an integrated program.

The Sierra Nevada Network includes four NPS units: Devils Postpile National Monument (DEPO), Sequoia and Kings Canyon National Parks (SEKI)—two distinct parks managed as one unit, and Yosemite National Park (YOSE). The parks cover approximately 658,000 hectares and are largely federally-designated wilderness (Table 1-2). The parks are located on the west slope of the Sierra Nevada, bounded primarily by US Forest Service lands (also mostly designated as wilderness with some timber harvest, grazing, reservoirs, and recreation) (Figure 1-2). Private lands occur predominately below an elevation of 914 m, along the western slope of the range (SNEP 1996a). The eastern boundary of YOSE and SEKI is the crest of the Sierra Nevada. The network includes a wide elevation range (Table 1-2) and supports a diverse assemblage of plants and animals.

Table 1-2. General statistics about Sierra Nevada Network parks as of 2004.

	DEPO	SEKI	YOSE
Size (ha)	324	349,581	308,075
Percent Wilderness	75%	85%	94%
Elevation Range (m)	2200-2500	400-4417	610-3998
Number of Visitors (2004)	114,788	1,003,539 (SEQU)[1] 595,091 (KICA)[2]	3,376,332

[1]SEQU: Sequoia National Park
[2]KICA: Kings Canyon National Park

Sierra Nevada Network parks were established to protect a variety of natural resources. These are discussed in the following sections.

1.5.1.1 Devils Postpile National Monument

Devils Postpile was established in 1911 to preserve "the natural formations known as the Devils Postpile and Rainbow Falls" for their scientific interest and for public inspiration and interpretation. The Devils Postpile formation is a dramatic mass of columnar-jointed basalt, the remnants of lava that flowed down the valley of the Middle Fork of the San Joaquin River less than 100,000 years ago. Nearly 20,000 years ago, a glacier overrode the fractured lava mass exposing a wall of columns 18 m high resembling a giant pipe organ. Nearby, Rainbow Falls, along the Middle Fork of the San Joaquin River, drops 31 m over a volcanic cliff. Devils Postpile is located high on the western slope of the Sierra Nevada in Madera County, California, near the headwaters of the Middle Fork of the San Joaquin River (Figure 1-3). *See Appendix A for more information on Devils Postpile National Monument.*

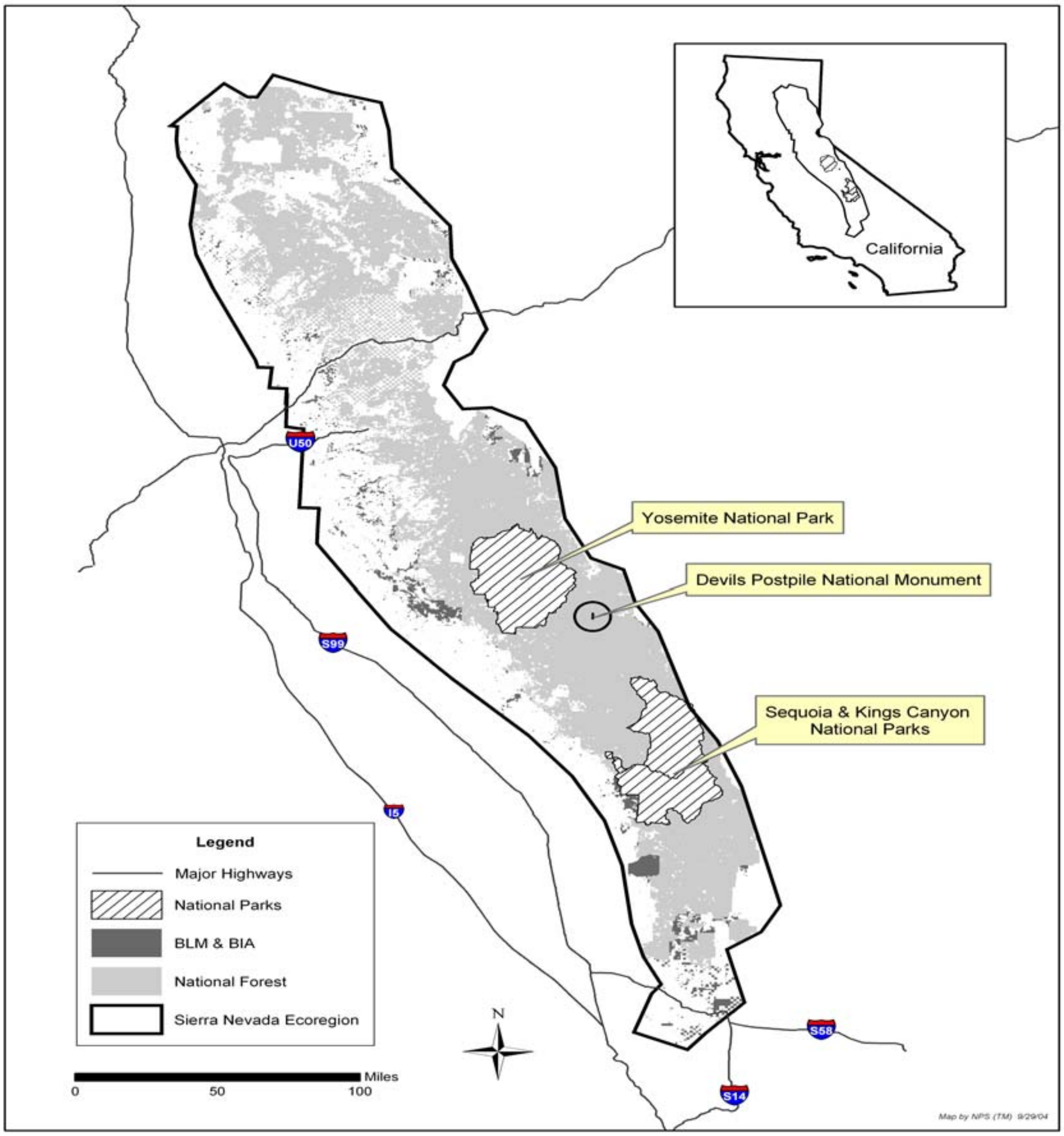


Figure 1-2. Sierra Nevada region showing Sierra Nevada Network parks and other federal lands.

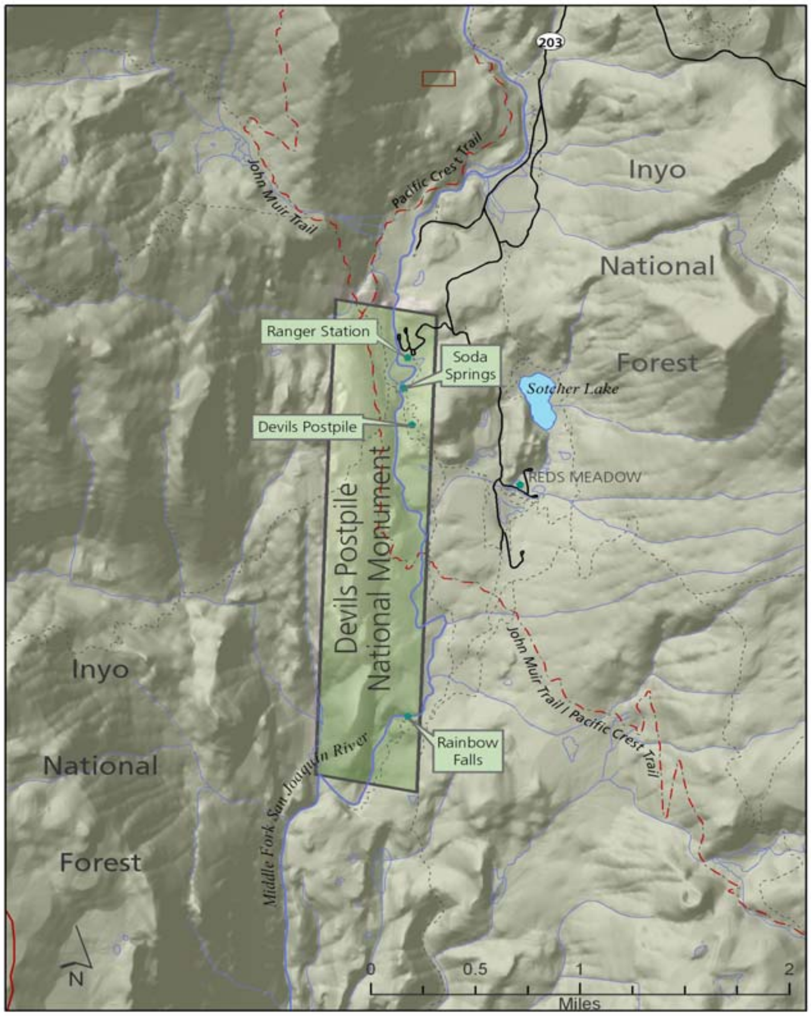


Figure 1-3. Devils Postpile National Monument.

1.5.1.2 Sequoia and Kings Canyon National Parks

Sequoia and Kings Canyon National Parks protect a variety of landscapes containing biological and cultural resources in the southern Sierra Nevada of California (Figure 1-4**)**. They are two separate national parks, created by acts of Congress fifty years apart. Today these parks are administered as a single unit. The parks are designated as an international Biosphere Reserve. Primary legislative purposes of the two parks are to preserve forest resources, particularly the giant sequoia groves, and to protect a vast wilderness for both scenic and recreational values.

Established September 25, 1890, Sequoia National Park is the second oldest national park in the United States (third if you include what is now Hot Springs National Park). The campaign to create the park was initiated and executed by San Joaquin Valley residents—focused on preserving the scenic and inspirational values of the region's giant sequoia (Sequoiadendron giganteum) groves. Since 1890, Sequoia National Park has undergone two major enlargements, both of which added high-elevation Sierra lands to the park, preserving both the headwaters of Kern and Kaweah river drainages and rugged, ice-sculptured alpine terrain that includes Mt. Whitney, the highest peak in the lower 48 states. Today, the best known features of Sequoia National Park remain the sequoia groves and high country. The Kern and Kings rivers are both designated national Wild and Scenic Rivers. Grant Grove National Park was designated in 1890. In 1940 this grove was incorporated into the much larger Kings Canyon National Park, whose features included other giant sequoia groves and great glacial canyons and scenic alpine headwaters of the South and Middle Forks of the Kings River. In 1965, the floors of Tehipite and Kings Canyon were added to protect scenic river segments from potential reservoir development. *See Appendix A for more information on Sequoia and Kings Canyon National Parks.*

1.5.1.3 Yosemite National Park

In 1864, Yosemite Valley and the Mariposa Grove of Big Trees were "granted" (known as the Yosemite Grant) by Act of the U.S. Congress to the State of California for "public use, resort and recreation," and to "be inalienable for all time". Thus, the significance of the area was recognized well before establishment of Yosemite National Park, and, nearly eight years before Yellowstone was set aside as the world's first national park.

In 1906, Congress accepted transfer of the Yosemite Grant back to the United States, adding it to Yosemite National Park, which had subsequently been established in 1890 "to preserve from injury all timber, mineral deposits, natural curiosities or wonders within the park area and to retain them in their natural condition." Several changes to the park boundary were made over the years. In 1984, Yosemite was designated a World Heritage Site.

Yosemite (Figure 1-5) is particularly noted for its textbook-perfect glacial features–domes, moraines, sheer rock walls, and hanging valleys–as well as its stunning waterfalls, "free-leaping" from the edges of hanging valleys over sheer granite walls. As John Muir noted, "… [e]very peak, ridge, dome, canyon, lake, basin, garden, forest, and stream testifies to the existence and modes of action of … scenery-making ice".

Yosemite protects a diversity of natural and cultural resources of the central Sierra Nevada, including the headwaters and portions of two national Wild and Scenic Rivers, the Merced and Tuolumne. The park also contains Hetch-Hetchy Reservoir on the Tuolumne, one of the major water supplies for the City of San Francisco. *See Appendix A for more information about Yosemite National Park.*

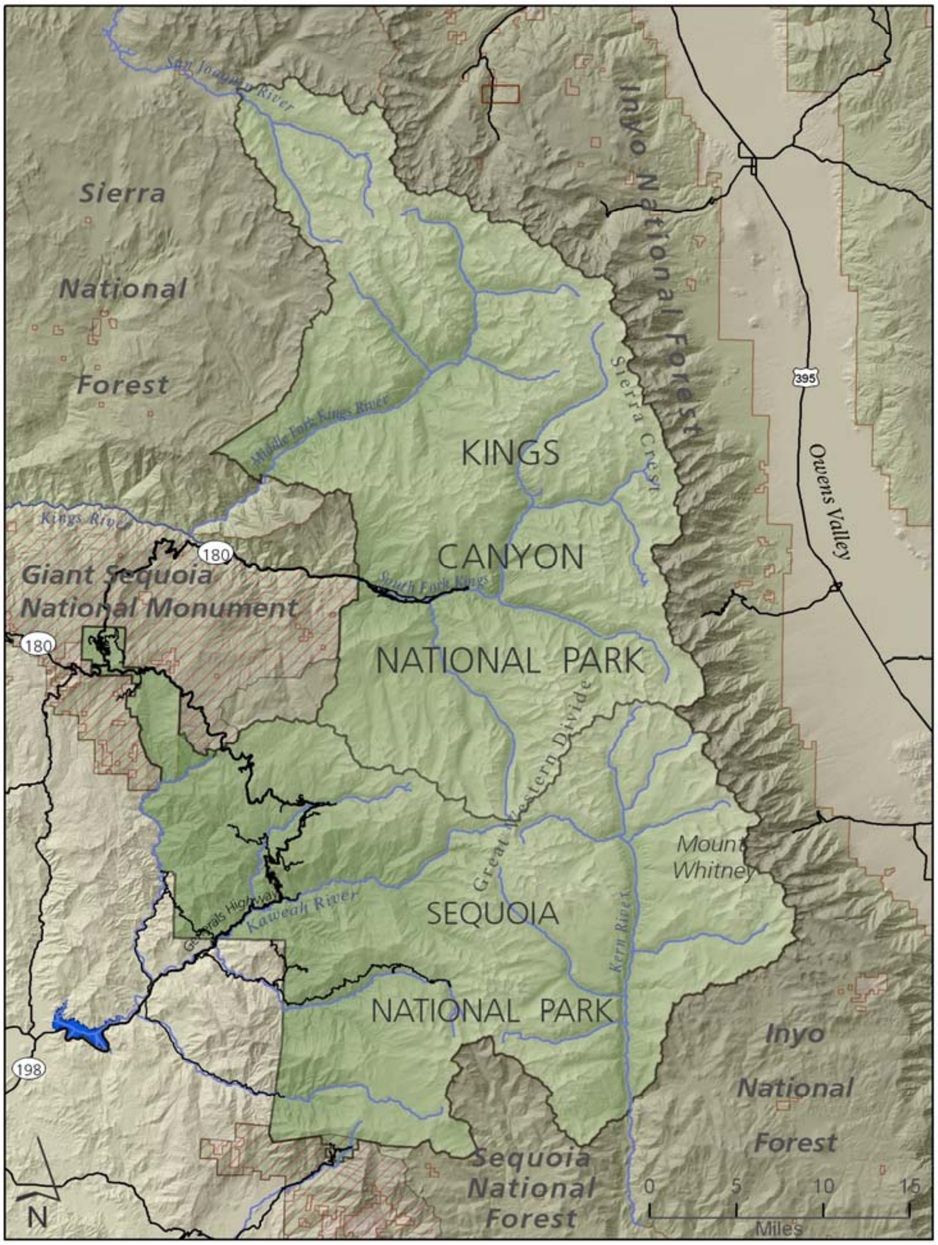


Figure 1-4. Sequoia and Kings Canyon National Parks.

Figure 1-5. Yosemite National Park.

1.6 Introduction to Sierra Nevada Ecosystems

Sierra Nevada Network parks lie within the Sierra Nevada, the highest and most continuous mountain range in California. The range runs 692 km from north to south, is up to 113 km wide, and encompasses almost 75,520 sq. km. The range is flanked by California's Central Valley on the west and the arid western edge of the Great Basin on the east (Figure 1-6).

Humans have been part of Sierra Nevada ecosystems for at least 9,000 years B.P. (Roper Wickstrom 1992). Numerous, distinct American Indian groups were widely distributed throughout the region well before settlement by Euramericans in the mid-19th century. Although the record is incomplete, archaeological evidence indicates that, prior to the 1850s, the American Indian population in the Sierra Nevada may have been as large as 90,000 to 100,000 people (Anderson and Moratto 1996).

Settlement patterns and resource use have historically reflected the export value of Sierra Nevada resources as commodities. The foothills became a focus of early attention for "Mother Lode" gold deposits, timber, water, and agriculture. An estimated 150,000-175,000 Euramericans moved into the Sierra Nevada from 1848 to 1860. The population in 1970 was about 300,000, and by 1990, over 650,000 people were living in the Sierra. About 70% of the current population is located on the west-side foothills, with other concentrations in the vicinities of the main Sierran highways. Projections suggest that the Sierra Nevada population will grow between 1.5 and 2.4 million residents by 2040 (SNEP 1996a).

The following sections contain an overview of the physical environment, the important role of fire, biological diversity and the major stressors and management issues for the Sierra Nevada region and parks. For readers who wish additional information about the larger Sierra Nevada region, see Sierra Nevada Ecosystem Project (SNEP), a detailed report requested by Congress in the Conference Report for Interior and Related Agencies in 1993 Appropriation Act (H.R. 5503), which authorized funds for a "scientific review of the remaining old growth in the national forests of the Sierra Nevada…, and for a study of the entire Sierra Nevada ecosystem by an independent panel of scientists, with expertise in diverse areas related to this issue" (SNEP 1996b). The report is a four-volume scientific assessment by an interdisciplinary team of scientists from land management agencies (primarily National Park Service and US Forest Service), universities, and private consulting groups. SNEP highlights what is known about physical, biological, ecological, social and institutional conditions for the Sierra Nevada region and presents individual and collective judgments about what this knowledge means for protecting the health and sustainability of Sierra Nevada ecosystems while providing resources to meet human needs.

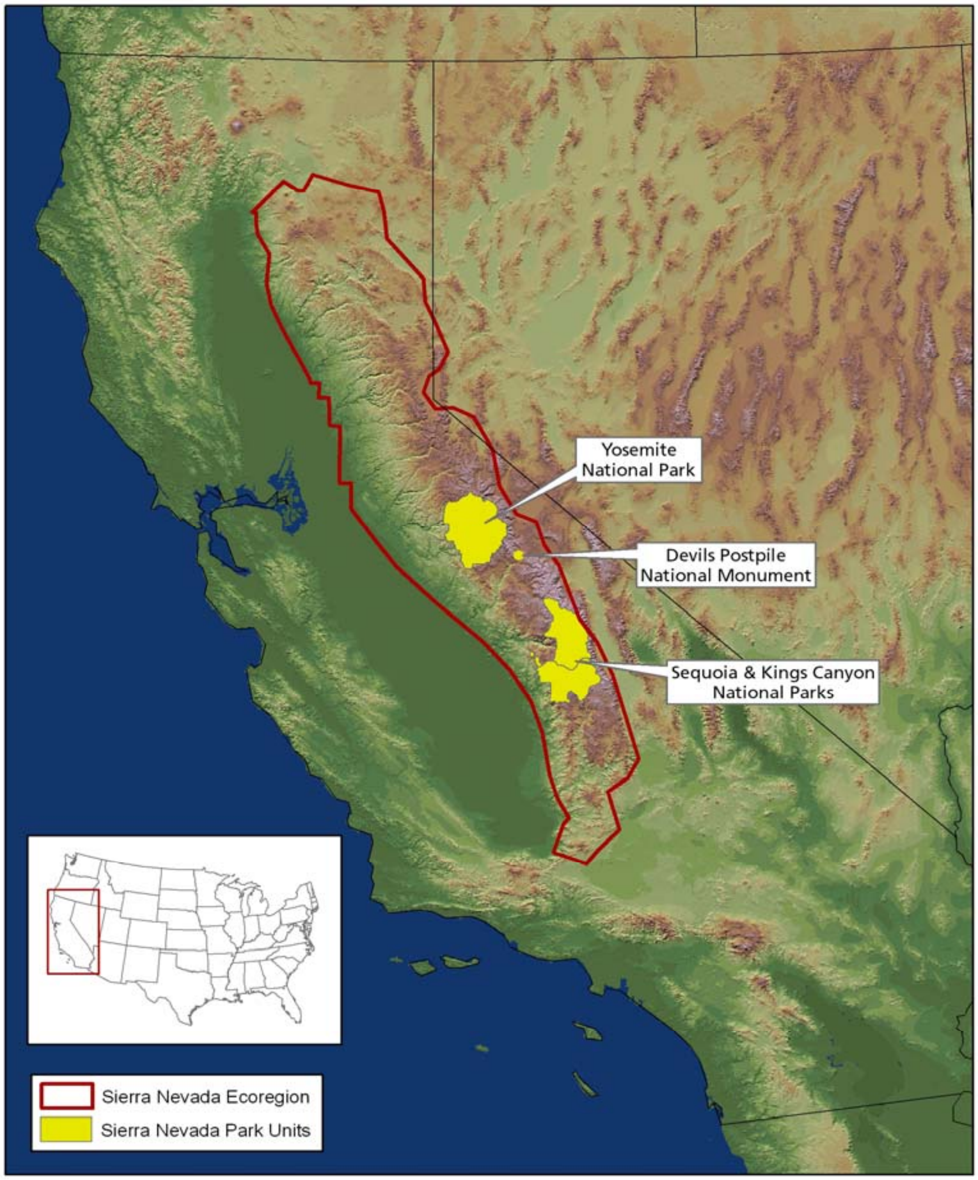


Figure 1-6. Sierra Nevada Network parks in the context of the larger region: Central Valley and Pacific Ocean to the west and Great Basin to the east.

1.6.1 Physical Setting

The Sierra Nevada is a tilt block asymmetric mountain range with a short, steep east escarpment. The western flank has a longer and gentler slope in Yosemite and the northern Sierra Nevada. Farther south, in Sequoia National Park and elsewhere in the southern Sierra Nevada, the western flank is much steeper, rising from near sea level to 4,818 meters in less than 100 kilometers. This striking elevational gradient characterizes the physical environment in the three large network parks (YOSE, SEQU, KICA) and creates coincident gradients in climate that drive the distribution of plants and animals. Climatic, geologic, and hydrologic processes have dramatic effects in the Sierra (

Figure 1-7).

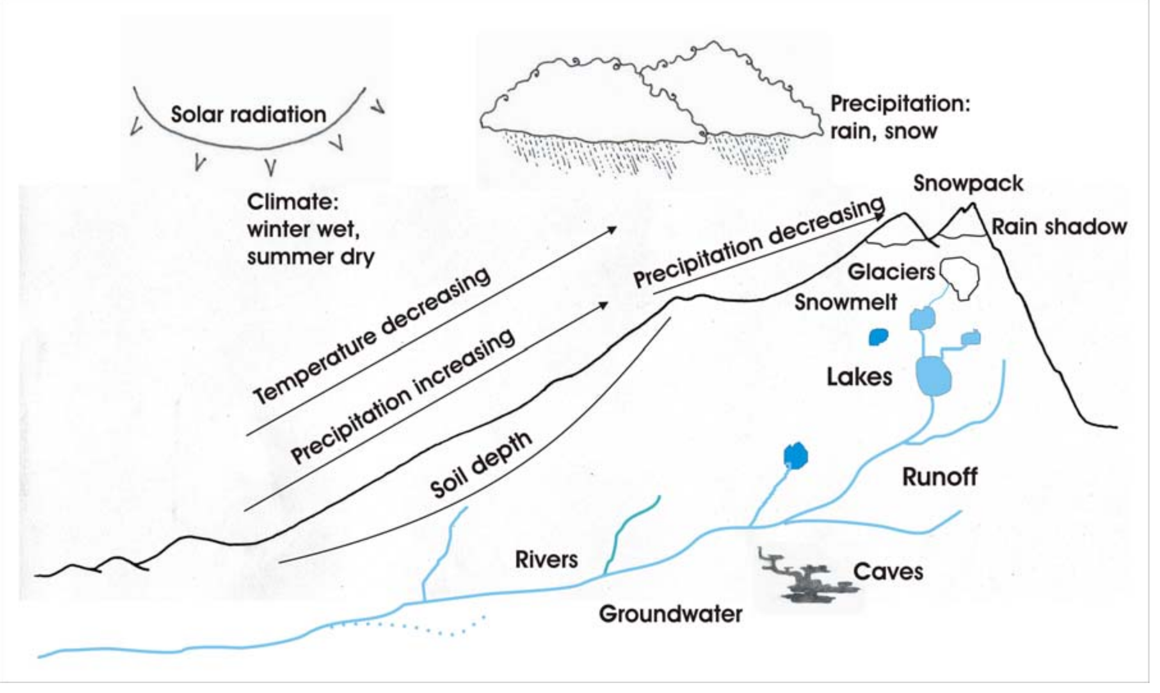


Figure 1-7. The Sierra Nevada physical setting illustrates the elevational gradient from the Central Valley and foothills (left side of image), up to the Sierra Nevada crest, and dropping back down more steeply along the east slope (right side of image). Climatic, geologic and hydrologic processes and features change along this gradient.

1.6.2 Climate

Strong climatic gradients develop with changing elevation in the Sierra Nevada, from west to east. Low to mid-elevations have a Mediterranean climate, characterized by hot, dry summers and cool, wet winters. Higher elevations are dominated by a microthermal (or Boreal) climate, characterized by having average temperatures of below -3°C during the coldest month. As a result, a steep temperature gradient parallels the elevation gradient; on average, each 100 m gain in elevation results in a 0.6 C° drop in air temperature. This lapse rate varies locally according to factors such as air speed, relative humidity, slope aspect, insolation, and vegetation cover (Stephenson 1988), but the general pattern holds true as one climbs from the hot lowlands to the alpine crest.

The west slope of the Sierra receives between 50 and 200 cm of rainfall each year, depending on elevation. Above 2100 m on the western slope, about 50% of precipitation falls as snow (Stephenson 1988), creating a significant snowpack in the montane and subalpine elevations. Just as mean temperature decreases with increasing elevation, so does the moisture-holding capacity of air. By the time winter storms reach the alpine, much of the moisture has been lost from the clouds and the amount of snow accumulating on the ground begins to decline with increasing elevation. East of the crest, the mountains create a rain shadow with significantly less moisture falling throughout the season. Precipitation also increases with latitude, due to Pacific jet stream position and subtropical high pressure cells. Across all elevations and latitudes, nearly 70% of precipitation falls from December through March and only about 4% from June through September (Stephenson 1988).

Climatic forces are a major driver of Sierra Nevada ecosystems. Current patterns of vegetation, water dynamics, and animal distribution in the Sierra are determined largely by cumulative effects of past and present climates.

1.6.3 Geology

The Sierra Nevada batholith is part of a more or less continuous belt of plutonic rocks that extends from the Mojave Desert to northwestern Nevada (Bateman et al. 1963). These granitic magmas intruded into preexisting metasedimentary and metavolcanic country rocks from ~215-70 million years ago, and were subsequently uplifted and tilted to the west, giving the range its asymmetric geometry with a short, steep east escarpment and a longer and gentler west slope (Whitney 1880, Lindgren 1911, Matthes 1960). Metamorphic units are still present as isolated roof pendants near the Sierra crest (Huber et al. 1989). With the onset of uplift, the erosive power of major streams was intensified due to their increased gradients, resulting in greater rates of incision and rolling hills that gave way to higher relief mountains with deep canyons cutting into the range's west flank (Huber 1987).

On the eastern flank of the mountains, volcanic activity at ~100 thousand years ago sent a lava flow into a valley, now designated Devil's Postpile NM, which cooled uniformly, contracted, and fractured into hexagonal columns. At ~10 thousand years ago, this formation was overridden by glaciers, exposing the columns. Evidence of the glacier—polish and scratches from glacial ice—remains atop the postpile (Clow and Collum 1986).

Several glacial periods in the Sierra Nevada, beginning at ~1 million years ago and lasting until ~10 thousand years ago, periodically covered much of the higher elevations of the Sierra Nevada parks and sent glaciers down many of the valleys (Yount and La Pointe 1997). Glacial ice quarried and transported vast volumes of rubble, which scoured and eroded the landscape. Small quantities of this debris accumulated along the margins of the glaciers and in widely distributed, hummocky piles called moraines. Landforms resulting from glaciation include U-shaped canyons, jagged peaks, rounded domes, waterfalls, and moraines. Granite that has been highly polished by glaciers is common in the parks and provides further evidence of glaciation. The innumerable natural lakes in the high Sierra Nevada are the result of glacial activity forming their basins. These lakes are transitory; eventually they will be filled with sediment and become meadows. Many lakes in the parks already have undergone this transformation (Huber 1987).

Sequoia and Kings Canyon National Parks contain more than 200 named caves (Despain 2003). The caves occur at elevations from 488 to 3,048 m, and include the longest cave in California, Lilburn Cave, with nearly 32 km of surveyed passage. Lilburn is a very complex maze cave with beautiful blue- and white-banded marble. Crystal Cave, developed with lights and trails at the end of the Great Depression, is one of the area's most popular tourist destinations. The caves provide unique habitats for animals, including bats, salamanders, small mammals, and invertebrates, some of which are endemic to specific caves (Despain 2003).

Soil and water chemistry characteristics in the Sierra Nevada are largely geologically controlled. Because the Sierra Nevada is underlain by mostly granitic rocks, soils that derive from these foundations are poorly developed, rocky, and generally low in fertility. Soils are thin due to recent glaciation, but tend to be thicker where not glaciated. In general, soil depth decreases with increasing elevation; deep alluvial soils of the Central Valley give way to shallow, decomposed granites and barren rock outcrops in alpine environments (Taskey 1995).

River basins are often underlain by surficial deposits, which are primarily glacial tills that occur in valley bottoms as lateral and recessional moraines, and are probably derived from the granitic bedrock present at higher elevations (Huber 1987, Bateman 1992). Stream water concentrations of chemical constituents such as cations, alkalinity, and silica tend to be higher in catchments with a high percentage of surficial cover (Clow et al. 1996), reflecting the importance of glacial till in controlling water chemistry. Bedrock geology across the Sierra Nevada is dominated by granitic intrusive rocks of fairly uniform composition (Huber 1987, Bateman 1992); however, slight variations in bedrock composition are reflected in the chemistry of surface waters. For example, according to Clow et al. (1996), streams of Yosemite in the upper Merced River basin that drain granite and light-colored granodiorite terranes have relatively low Ca:Na ratios, while streams that drain dark-colored granodiorites and tonalites tend to have higher ratios. These few preceding examples exhibit how the fundamental ecosystem building blocks of water and soils are inextricably linked to the underlying geology in the Sierra Nevada.

1.6.4 Air Resources

Kings Canyon, Sequoia, and Yosemite National Parks are designated Class I air sheds under the Clean Air Act (1977 amendment). As such, the parks are afforded the greatest degree of air quality protection, and the National Park Service is required to do all it can to ensure that air quality related values are not adversely affected by air pollutants. Devils Postpile National Monument is designated a Class II air shed. There is still a mandate to protect Class II air sheds; however, it is not as stringent compared to Class I air sheds. Despite these designations, air quality in the Sierra Nevada is impaired, threatening natural resources, human health, and visitor experiences *(See section 1.7, Sierra Nevada Ecosystem Stressors, and also Appendix C).*

In addition to air quality, Sierra Nevada parks contain other air resources, including night sky and natural soundscapes that are intrinsic elements of the environment (just as water and wildlife are intrinsic values). Night sky visibility is an important aesthetic value of wilderness and its protection has been added to the responsibilities of National Park Service managers. Light pollution is not confined to cities. Excessive glare, urban sky glow, and poorly designed lighting threaten dark skies in the Sierra Nevada. Natural soundscapes are inherent components of "the scenery and the natural and historic objects and the wild life" and are protected by the National Park Service's Organic Act. They are vital to the natural functioning of many parks and may provide valuable indicators of ecosystem condition (National Park Service 2001a).

1.6.5 Water Resources

SIEN parks span seven major watersheds: Tuolumne, Merced, San Joaquin, Kings, Kaweah, Kern and Tule (Figure 1-8). Runoff from these watersheds drains into the San Francisco Bay/Sacramento–San Joaquin Delta in the north and the Tulare Lake Basin in the south. Yosemite, Sequoia, and Kings Canyon parks contain most of the headwater streams. Devils Postpile National Monument is located within the upper Middle Fork of the San Joaquin watershed. The headwaters of the Middle Fork of the San Joaquin begin 14.1 km upstream of the monument at Thousand Island Lake. The watershed area above the monument is managed by Inyo National Forest. The Sierra Nevada parks protect a diversity of water resources, including over 4,500 lakes and ponds, thousands of kilometers of rivers and streams, seeps, wet meadows, waterfalls, hot springs, mineral springs and karst springs.

Water dynamics in the Sierra Nevada are a critical component of both the parks' ecosystems and the larger California water infrastructure. The snow pack acts as a temporary reservoir, storing water that will be released during the warmer and drier months. Peak runoff typically occurs late May to early June. Water is captured and stored for summer use in a series of reservoirs in the Sierra foothills. Reservoirs are primarily located downstream of park boundaries, although there are exceptions, including Hetch Hetchy and Lake Eleanor in Yosemite and four small dams in Sequoia.

Sierra Nevada ecosystems produce approximately $2,200,000,000 in annual revenue. Water accounts for more than 60% of these dollars (SNEP 1996b). Primary uses include irrigated agriculture, domestic water supplies, hydroelectric power, recreation and tourism. Water resources and associated aquatic and riparian habitats also have high ecological value. Approximately 21% of vertebrates and 17% of plants in the Sierra Nevada are associated with aquatic habitats (SNEP 1996b).

The California Water Resources Control Board (WRCB) and nine Regional Water Quality Control Boards (RWQCB) are responsible for protecting and enhancing California's water resources under the Porter-Cologne Water Quality Control Act. Each RWQCB adopts Basin Plans, which contain beneficial use designations, water quality

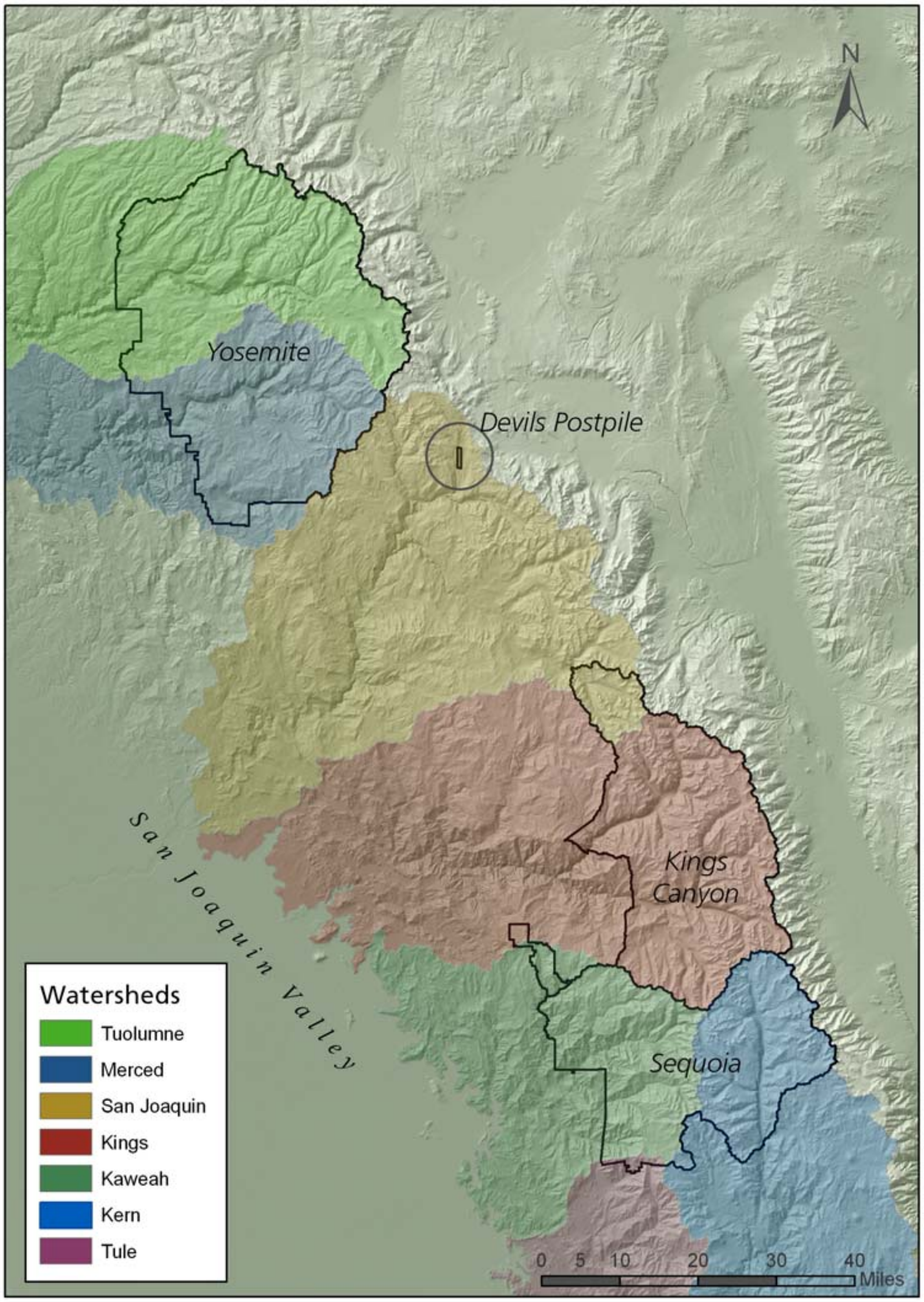


Figure 1-8. Watersheds in Sierra Nevada Network parks.

objectives, and implementation programs. Sierra Nevada Network parks fall under jurisdiction of the Central Valley RWQCB and have waters contained in both the Sacramento-San Joaquin and Tulare Lake basins. Under sections 305(b) and 303(d) of the Clean Water Act, California must assess overall health of the state's waters and identify waters that are not attaining water quality standards. The State must compile water quality limited waters in a 303(d) list and initiate a process to bring listed waters back into compliance. Sierra Nevada Network parks do not contain any 303(d) listed waters (State Water Resources Control Board 2002). The State also has authority to designate waters as Outstanding Natural Resource Waters - the highest level of protection afforded to a water body under the Clean Water Act. Sierra Nevada Network parks do not have any Outstanding Natural Resource Waters, but waters in national parks are strong candidates for this designation.

There are four Wild and Scenic Rivers in the parks - the Middle and South Forks of the Kings River (98.5 km) and the North Fork of the Kern River (46.5 km) in Sequoia and Kings Canyon, and the Merced (130.0 km) and Tuolumne (87.0 km) rivers in Yosemite.

The Sierra Nevada Ecosystem Project (SNEP) identified aquatic and riparian systems as the most altered and impaired habitats in the Sierra Nevada (SNEP 1996b). Primary reasons for deterioration are changes in flow regimes, disturbances from land use practices, and introduction of non-native organisms. Despite these impacts on aquatic and riparian habitats, basic hydrologic processes and water quality remain in relatively good condition (Kattelmann 1996). Hydrologic modifications and degraded water quality are of greatest concern downstream of the parks in foothill reservoirs and the Central Valley. Devils Postpile, Sequoia, Kings Canyon and Yosemite protect some of the least altered aquatic ecosystems in the Sierra Nevada.

See Appendix D for a more detailed description of Sierra Nevada water resources.

1.7 Fire: A Key Process

Fire has played a pivotal role in shaping ecosystems and landscapes in the Sierra Nevada for many millennia (Davis and Moratto 1988, Smith and Anderson 1992, SNEP 1996a, Anderson and Smith 1997). It affects numerous aspects of ecosystem dynamics such as soil and nutrient cycling, decomposition, succession, vegetation structure and composition, biodiversity, insect outbreaks, and hydrology (Kilgore 1973, SNEP 1996a). Historically, fire frequency, size, intensity, and severity varied spatially and temporally across the landscape depending on number of ignitions, climate, elevation, topography, vegetation, fuels, and edaphic conditions (Skinner and Chang 1996). Fires were common, often burning for months and reaching large sizes.

Periodic fires performed many ecological functions within Sierran ecosystems prior to Euramerican settlement. Frequent surface fires in many vegetation types minimized fuel accumulation while their variable nature helped create diverse landscapes and forest conditions (Stephenson et al. 1991, SNEP 1996a). Fires tended to be low to moderately severe, with high-severity portions (intense enough to kill most large trees) generally restricted to localized areas of a fraction of an acre to a few acres. Extensive research in mixed-conifer forests has shown that low intensity surface fires were common and tended to keep the forests open (Biswell 1961, Hartesveldt and Harvey 1967, Weaver 1967, Kilgore 1971, 1972, Weaver 1974, Harvey et al. 1980).

Many species and most plant communities show clear evidence of adaptation to recurring fire, indicating that fire occurred regularly and frequently, particularly in the chaparral and mixed-conifer communities, where many plant species have life history attributes tied to fire for reproduction or as a means of competing with other biota. Fire damaged or killed some plants, setting the stage for regeneration and vegetation succession. Many plants evolved fire-adapted traits, such as thick bark, and fire-stimulated flowering, sprouting, seed release, and/or germination (Chang 1996). Fire influenced soil and forest floor processes and organisms by consuming organic matter and inducing thermal and chemical changes. It also affected the dynamics of biomass accumulation and nutrient cycling at a variety of spatial scales. These effects in turn influenced habitats and the distribution and occurrence of many species.

Fire regimes are defined according to specific variables including frequency, severity, season, duration, magnitude, spatial distribution, and type of fire (Gill 1975, Heinselman 1981). These characteristics may vary through time and across the landscape in response to climatic variation, number of lightning ignitions, topography, vegetation, historic events, and cultural practices (SNEP 1996a). Fire regime types for major Sierra Nevada plant communities vary from short-interval, low-intensity surface fires in ponderosa pine and blue oak woodland to long-interval, variable intensity fires that occur in lodgepole pine forests and include numerous other fire regimes in diverse vegetation types of the Sierra Nevada.

Variation in fir frequency exists locally and at large scales, and is affected by site productivity, potential for ignition, and other factors. General patterns of pre-Euramerican fire frequencies are apparent at several scales in the parks. Differences in average fire frequency are also apparent in different vegetation types (Table 1-3 and Figure 1-9). On the west slope of the Sierra, frequencies were reconstructed using fire-scarred trees. Data show an inverse relationship between number of fires and elevation (Caprio and Swetnam 1995, Swetnam et al. 1998, Caprio 2000).

Short-term climatic variation had a significant impact on past burn patterns and fire severity. Historically, on the west slope of the Sierra Nevada, specific fire years have been identified (years in which fires have been recorded at sites throughout the southern Sierra Nevada). These usually occurred during dry years (Brown et al. 1992, Swetnam et al. 1992, Swetnam 1993, Swetnam et al. 1998). Analysis of millennial-length fire histories from giant sequoias also document long-term variation (1,000-2,000 years) in the fire regime associated with climatic fluctuations (Swetnam 1993). These data suggest more frequent but smaller fires occurred during the Medieval Warm Period (A.D. 1000 - 1300) and fewer larger fires during cooler periods (A.D. 500 - 1000 and after A.D. 1300). These fluctuations indicate that characteristics of fire regimes are dynamic over long time periods.

Although fire regime characteristics may vary through time and across the landscape, from the late 1890s through the 1960s, Sierra Nevada park and national forest personnel attempted to suppress all fires, and these efforts met with a fair degree of success. Consequently, numerous ecosystems that had evolved with frequent fires have since experienced prolonged periods without fire (Swetnam et al. 1992, Swetnam 1993, Caprio and Graber 2000, Caprio et al. 2002, Caprio and Lineback 2002). This change in fire regime has severely modified ecosystems (*See section 1.7 Sierra Nevada Ecosystem Stressors).*

Table 1-3. Mean and maximum fire return intervals for major vegetation classes in Sierra Nevada Parks. The table also includes quality of the knowledge used to calculate or estimate fire return intervals and sources used to obtain this information.

Vegetation Class	Mean (Max) Fire Interval-Years	Knowledge	Reference
Very Low Fire Frequency			
Lodgepole Pine	102 (163)	v. poor	5, 6,18
Subalpine Conifer	187 (508)	poor	5, 9
Low Fire Frequency			
Red Fir Mixed-conifer	30 (50)	poor	1, 4, 5
Xeric Mixed-conifer	30 (50)	v. poor	5, 7, 8, 17
Montane Chaparral	30 (75)	estimated	12
Meadow	40 (65)	estimated	8
Foothills Chaparral	30 (60)	estimated	12
Moderate Fire Frequency			
Foothills Hardwood & Grassland	10 (17)	v. poor	5, 10, 11
Mid-elevation Hardwood	7 (23)	v. poor	3, 19
High Fire Frequency			
White Fir Mixed-conifer	10 (16)	good	1, 2
Giant Sequoia	10 (16)	good	13, 14, 15
Very High Fire Frequency			
Ponderosa Mixed-conifer	4 (6)	good	1, 2, 3, 16, 17

Notes: Data are prior to 1860 (1870 for subalpine conifer). Primary source(s) also listed in References. Fire frequency regime classes for each major vegetation class are based on mean maximum fire-return intervals (i.e., average of the longest fire-return intervals). Frequency classes were used to reconstruct fire frequency regimes spatially across the parks.

1(Caprio and Swetnam 1993, 1994, Caprio and Swetnam 1995); **2** (Kilgore and Taylor 1979); **3** (Stephens 1997) unpublished data in (Skinner and Chang 1996); **4** (Pitcher 1981, 1987); **5** Caprio unpublished data 2000 ; **6** (Keifer 1991); **7** Taylor, unpublished data in (Skinner and Chang 1996); **8** Skinner, unpublished data in Skinner and Chang 1996; **9** Caprio, Mutch, and Stephenson unpublished data ; **10** (Mensing 1992); **11** (McClaren and Bartolome 1989); **12** (SNEP 1996a); **13** (Swetnam et al. 1990); **14** (Swetnam et al. 1992); **15** (Swetnam 1993); **16** (Warner 1980); **17** (McBride and Jacobs 1980); **18** (Sheppard 1984); **19** (Stephens 1997).

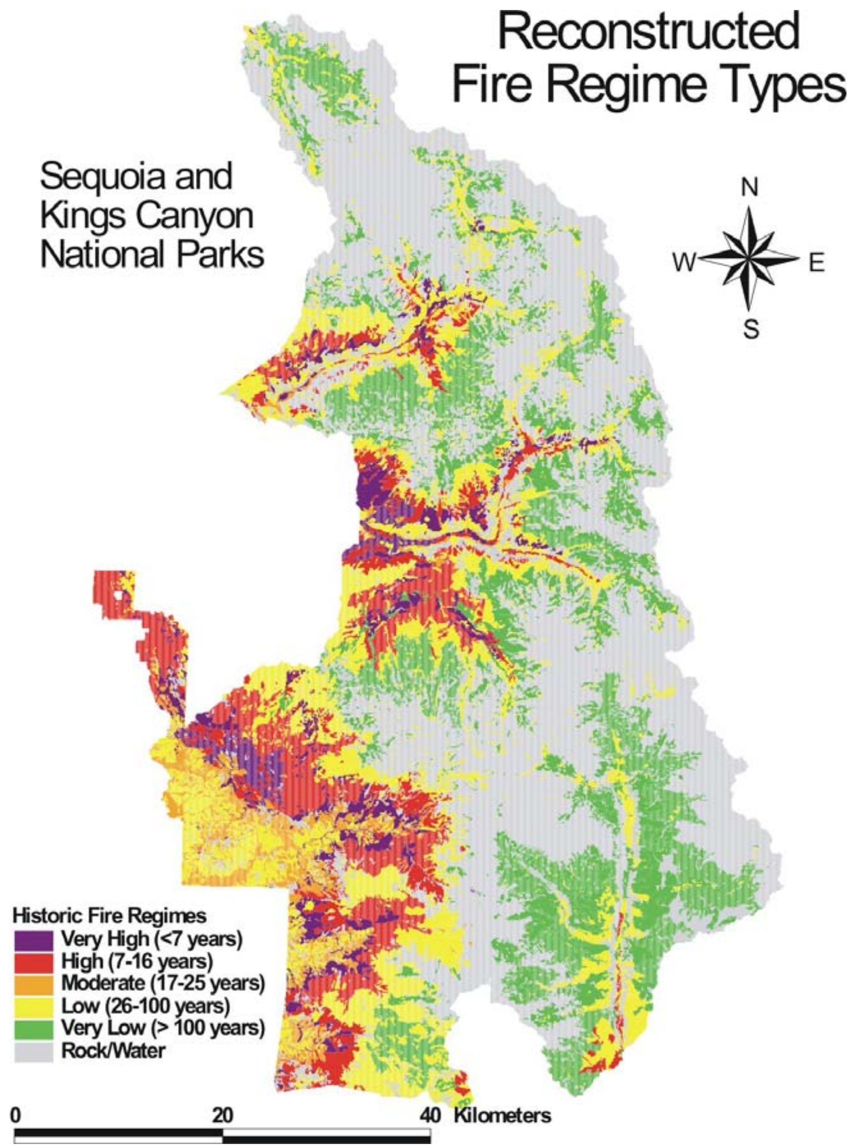


Figure 1-9. Mean fire-return intervals (i.e., historic fire regimes), or mean time between fires, for different vegetation or cover classes in Sequoia and Kings Canyon National Parks (Caprio and Lineback 2002). Sources used to construct these fire regime types are summarized above in Table 1-3. A similar map exists for Yosemite National Park (van Wagtendonk et al. 2002).

1.7.1 Plant and Animal Diversity

The striking elevational gradient and topographic variability in the Sierra Nevada result in a high diversity of habitats for plants and animals. Sequoia, Kings Canyon and Yosemite National Parks, the largest and least fragmented habitat blocks in the Sierra Nevada, are recognized for their importance in protecting the long-term survival of certain species and the overall biodiversity of vegetation and wildlife in the region (SNEP 1996a).

The parks' vegetation can be categorized broadly into the following vegetation zones: oak woodland, chaparral scrubland, lower montane, upper montane, subalpine, and alpine (Figure 1-10). Vegetation changes dramatically along west-east elevation gradients from the lowest elevation oak woodlands up to ancient foxtail pines and western juniper, krumholz whitebark pine, and alpine perennial herbs at the highest elevations. While the parks' eastern boundaries are along the Sierra Nevada crest, some areas have plant communities showing a mix of west and east slope affinities, such as Devils Postpile National Monument (Arnett and Haultain 2004). Sparse forests on the upper east slope of the Sierra Nevada grade into semi-arid Great Basin scrublands in the mountains' rain shadow.

In its entirety, the Sierra Nevada region supports over 3,500 native vascular plant species, comprising half of the approximately 7,000 vascular plant species in California. Sierra Nevada parks support more than 20% of this California total.

Sequoia and Kings Canyon support over 1,200 vascular plant species and more than 1,500 taxa, including subspecies and varieties (Akin et al. 2004). Sequoia and Kings Canyon are known to support 138 special-status vascular plant species (Norris and Brennan 1982, Stokes 2003)) and at least 200 non-native invasive vascular plant species (Gerlach et al. 2002). *See Appendices E and F for additional information on non-native species in all network parks.*

Yosemite supports at least 1,560 vascular plant taxa, including subspecies and varieties (Botti 2001, Johnson 2003). The park is known, or has high potential, to support at least 160 special-status vascular plant species (Moore 2003, Stokes 2003)), and is known to support over 180 non-native invasive vascular plant species (Gerlach et al. 2002, Johnson 2003).

Devils Postpile supports 380 vascular plant taxa, including eight non-native invasive plants (Arnett and Haultain 2004).

Bryophyte collections have been made in all network parks (Steen 1988, Norris and Shevock 2004b, a, Shevock In progress). Surveys have documented 350 moss species in the southern Sierra Nevada, and 300+ species are estimated to occur in the central Sierra (Shevock 2002). Lichen surveys have been limited (Smith 1980, Wetmore 1986); however, estimates suggest approximately 250 macrolichen species and a similar number of crustose species could occur in Sierra Nevada parks (Neitlich 2004).

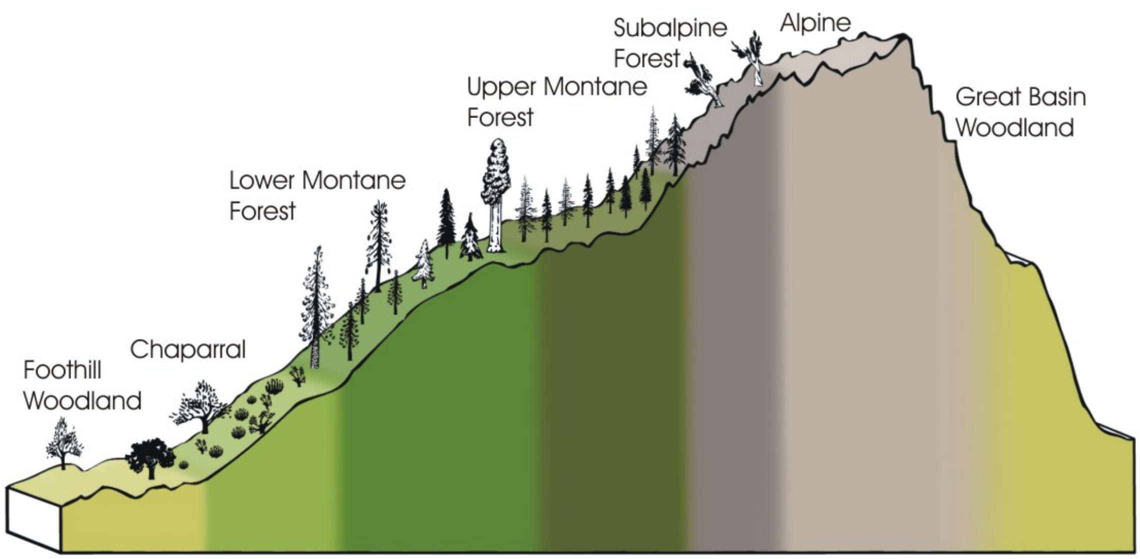


Figure 1-10. Sierra Nevada vegetation zones along its west-to-east elevation gradient, from the Central Valley and foothills, up to the Sierra Nevada crest, and down its east slope. The diverse topography results in high diversity of plants and animals. *Illustration by Justin Hofman***.**

Approximately 300 terrestrial vertebrate species use the Sierra Nevada as a significant part of their range; another 100 species use the Sierra Nevada as a minor part of more extensive home ranges. Of 401 terrestrial species (not including fishes) documented for the Sierra Nevada, 232 are birds, 112 are mammals, 32 are reptiles, and 25 are amphibians (Graber 1996). The mountain range includes about two-thirds of the bird and mammal species and about half the amphibians and reptiles in the state of California (Graber 1996). The Sierra Nevada parks support over 280 native vertebrates, including fishes.

The foothills of the parks become increasingly important as similar areas outside park boundaries succumb to heavy grazing and residential development. Most plant communities in the parks are comprised of native plant species, but foothill woodlands are dominated by non-native annual grasses introduced to California during the mid 19th century. Low elevation chaparral communities are dominated by dense thickets of thick-leaved shrubs. Many of these shrubs exhibit adaptations to fire and drought, both of which strongly influence the foothill environment. Particularly important resources to wildlife in these areas include blue oak (*Quercus douglasii*) acorns and chaparral shrub berries (especially manzanita) as well as other forage and cover.

Blue oak woodland.

Sierra Nevada montane forests form some of the most extensive stands of old growth mixed-species coniferous forest remaining in the United States. These mixed-coniferous forests support a remarkable diversity of tree species: ponderosa pine (*Pinus ponderosa*), incense-cedar (*Calocedrus decurrens*), white fir (*Abies concolor*), red fir (*Abies magnifica*), sugar pine (*Pinus lambertiana*), and giant sequoia (*Sequoiadendron giganteum*).

Giant sequoias occur naturally only in the Sierra Nevada, where they are found in approximately 75 separate groves. The 42 named groves in Kings Canyon, Sequoia, and Yosemite contain roughly one-third of all naturally occurring sequoia trees.

As one moves higher in elevation to the upper montane zone, mixed-coniferous forest is replaced by nearly pure stands of red fir and lodgepole pine (*Pinus contorta*), with some Jeffrey pine (*Pinus jeffreyi*), and western juniper (*Juniperus occidentalis*). Lodgepole pines tend to occur in moist lowlands, as well as in drier sites on benches and ridges. Animal diversity is at a maximum in lower and upper montane forest habitats, due to the relatively mild climate, and the mixture of habitat types and plant species present.

Red fir forest.

In the subalpine zone, western white pine (*Pinus monticola*), mountain hemlock (*Tsuga mertensiana)*, lodgepole pine (*Pinus contorta*), foxtail pine (*Pinus balfouriana*), and stands of whitebark pine (*Pinus albicaulis*) intermix with subalpine meadows and lakes. In rocky alpine areas, where very short growing seasons and harsh winter conditions exist, trees give way to low-growing, perennial herbs. Plants often form ground-hugging mats or hummocks as a result of warmer temperatures closer to the surface. Winter snow provides insulation from extreme low temperatures and desiccating winds. Although exposed granite outcroppings, talus slopes, and boulder fields dominate this zone, these rocky habitats support a surprisingly rich flora.

Clark's Nutcrackers are specialized for feeding on large pine seeds. Its behavior, annual cycle, and even its morphology are closely tied to this diet and thereby closely tied to subalpine white pine forests. Alpine talus fields are inhabited by pikas, marmots, voles, mice, shrews; endangered toads, many diverse invertebrate assemblages, and various other types of animals. Scattered bands of Sierra bighorn sheep (a federally endangered species), can still be found in some of the highest and most remote areas along the crest.

Meadows and wetlands, while occupying a small fraction of the land area in the Sierra Nevada, are a key ecosystem element in the Sierra Nevada. Meadows are extremely productive ecosystems, and provide critical breeding and foraging habitat for a suite of animal species in the Sierra Nevada. Recent work demonstrated the importance of Sierra Nevada meadows as breeding grounds for invertebrates, which form the energetic basis of many food chains (Holmquist and Schmidt-Gengenbach 2005). Many insects breed in meadows, and then disperse into adjacent forests and woodlands as the season progresses, where they are important as food sources and as pollinators. Dozens of bird species, including the federally endangered Willow Flycatcher and the state-listed Great Grey

Owl, use meadows for foraging, nesting, or both. Mule deer take advantage of the cover provided by montane meadow vegetation by hiding their fawns under the dense herbaceous canopy. Small mammals, such as ground squirrels, pocket gophers, and voles, feed on both above and below ground meadow vegetation. Animals such as frogs, toads, and shrews frequent the moist vegetation edging stream channels.

Aquatic systems (lakes, ponds, streams and rivers) are some of the most biologically impaired systems in the Sierra Nevada. While altered hydrology (diversions, dams) plays a lesser role impacting aquatic life in the parks compared to outside the parks, they are locally important in some developed areas and at Hetch-Hetchy Reservoir in Yosemite. The introductions of non-native fish to Sierra Nevada lakes and bull frogs to lower elevation lakes and stream courses have had devastating effects on native biota. Foothill yellow-legged frogs are extirpated, and mountain yellow-legged frogs and Yosemite toad are warranted (but currently precluded) for federal listing as endangered. In addition to feeding on tadpoles, non-native fish have altered invertebrate community composition (Stoddard 1987, Matthews et al. 2002), affecting food sources for other animals such as aquatic snakes and Pacific tree frogs (Matthews et al. 2002) and birds (Knapp et al. 2005)**.** *See Appendices E and F for additional information on non-native species in all network parks.*

The parks support a large number of special status, rare, or endemic species (Appendix F). Rare local geologic formations and the unique soils derived from them have led to the evolution of ensembles of plant species restricted to these habitats. These include limestone outcrops in Sequoia and Kings Canyon National Parks and a unique contact zone of metamorphic and granitic rock in the El Portal area of Yosemite National Park, where several state-listed taxa are found. Karst environments have recently been shown to harbor assemblages of rare and endemic invertebrates (Despain 2003, Krejca In progress) as well as providing roosting sites for bat colonies. Seventeen species of bats are documented for Sierra Nevada parks, nine of which are either Federal Species of Concern or California Species of Special Concern (Pierson et al. 2001, Pierson and Rainey 2003).

While Sierra Nevada parks offer important protected habitats for a diverse assemblage of plants and animals from direct pressures of development, logging, mining, extensive water diversions, and other human impacts, they do not protect park resources from the larger-scale stressors of pollution, altered fire regimes, invasive non-native species, and anthropogenic climate change.

1.8 Sierra Nevada Ecosystem Stressors and Resource Threats

Network park managers and researchers, using best professional judgment, a substantial supporting body of research, and findings from the Sierra Nevada Ecosystem Project (SNEP 1996a), have identified five important systemic stressors posing the greatest threat to Sierra Nevada network parks. Because of their potential to cause greater impact across a large landscape, only these systemic stressors are discussed in detail. Table 1-4 lists both broad scale and localized stressors and management issues identified for individual Sierra Nevada Network parks.

Table 1-4. Listing of resource issues and stressors, SIEN parks.

Stressors and Issues of Concern	DEVILS POSTPILE	SEQUOIA & KINGS CANYON	YOSEMITE
Air and Climate			
Climate change	●	●	●
Precipitation change & spring runoff pattern	●	●	●
Elevated ozone		●	●
Particulate matter		●	●
Smoke management		●	●
Visibility Impairment		●	●
nitrogen deposition		●	●
Persistent organic pollutants		●	●
Water			
Recreational use (litter, human waste, stock)	●	●	●
Reduction in snowpack, icefields, glaciers	●	●	●
Change in snowmelt timing	●	●	●
Road runoff	●	●	●
Riverbank compaction & erosion	●	●	●
Atmospheric contaminants		●	●
Elevated nutrients		●	●
Diversions and dams		●	●
Altered fire regimes and resultant effects on flow and chemistry		●	●
Groundwater withdrawal		●	●
Water diversion		●	●
Arsenic from volcanic sources--potential threat to drinking water	●		
Better hydrology baseline data needed	●		
Old mines		●	
Biologic			
Wildlife access to human food (e.g., bears, coyotes, raccoons)	●	●	●
Amphibian decline		●	●
Effects of altered fire regimes on plant and animal communities	●	●	●
Lack of adequate baseline information, especially for invertebrates, non-vascular plants	●	●	●
Meadows/wetlands and recreation (grazing, trampling, fragmentation by trails)	●	●	●
Non-native, invasive plants, esp. at low to mid elevations	●	●	●
Non-native animals (e.g., fish, birds)	●	●	●
Non-native rust: White Pine Blister Rust and pine mortality		●	●
Hazard tree management	●	●	●
Potential effects of accelerated climatic change on plant and animal distributions	●	●	●
High concentrations of visitor use in some areas		●	●

Stressors and Issues of Concern	DEVILS POSTPILE	SEQUOIA & KINGS CANYON	YOSEMITE
Climbing impacts to vegetation growing on granite			●
Snowmobile trespass	●		●
Large-scale marijuana plantations and resulting resource damage		●	
Geology & Soils			
Effects of climbing on large granite faces (hardware litter, rock face damage)			●
Sedimentation and erosion after severe fire	●	●	●
Development in rockfall zones			●
Erosion of riverbank soils due to visitor use			●
Soil compaction due to visitor use		●	●
Effects of rockclimbing	●	●	●
Roads across braided stream channels			●
Effects of contaminants originating from waste accumulation sites (e.g., old dumps)			●
Loss of glacial polish on postpile columns (trailing, erosion)	●		
Erosion of fragile volcanic soils from social trailing	●		
Volcanic and earthquake activity (regional)	●		
Erosion and undercutting along riverbanks--visitor use	●		●
Roads in rockfall zones		●	●
Damage to caves (e.g., visitation, vandalism)	●		●
Ecosystem Processes			
Altered fire regimes	●	●	●
Altered biogeochemical cycles (elevated PO_4, NOx, NH_4)	●	●	●
Wilderness			
Preserving natural soundscape (e.g., overflight issues)	●	●	●
Preservation of dark night sky (from light intrusion)	●	●	●
Snowmobile trespass	●		●
Day use	●	●	●
Habitat Fragmentation, Loss, and Land-use Change (e.g., development)			
Development, logging, grazing outside boundaries	●	●	●
Roads and developed areas inside boundaries		●	●
Logging, grazing, ski resort, and other development outside boundaries	●		
Potential groundwater pumping by Mammoth Lakes at San Joaquin Ridge-reduced flows	●		
Dams–impediment to fish migration			●

Sources: Park vital signs workshop reports ((Mutch and Lineback 2001, Mutch 2002, Mutch and Thompson 2003); Evaluation of Existing Water Resources Information in Sierra Nevada Network for the Vital Signs Water Quality Monitoring Plan (Appendix D); water resources scoping meeting summary (Heard and Mutch 2003); Sequoia and Kings Canyon Resources Management Plan (Sequoia And Kings Canyon National Parks 1999); Yosemite National Park Resources Management Briefing Package (National Park Service 2003b); Sierra Nevada Ecosystem Project Report (SNEP 1996a); and park staff.

1.8.1 Key Stressors

The five systemic stressors, posing the greatest threat to Sierra Nevada network parks, are as follows:

- climate change (rapid anthropogenic)
- altered fire regimes
- non-native invasive species
- air pollution
- habitat fragmentation and human use

These five stressors are discussed in detail below (sections 1.7.2 through 1.7.6); of the five, climatic change may have the greatest potential to affect ecosystems in part because of its pervasiveness and extent across ecosystems as well as synergistic effects with other stressors. Conversely, localized stressors (e.g., vegetation trampling by livestock or park visitors, small dams and diversions, and mines) generally affect small areas of Sierra Nevada Network parks, although they might threaten special-status species or alter rare habitats.

1.8.2 Climate Change

Average global temperatures have been rising, and the earth's atmosphere is warmer than at any point during the last several centuries (Mann et al. 1998). There is broad international consensus among climatologists and atmospheric scientists that "most of the observed warming over the last 50 years is likely [attributable to a human-induced] increase in greenhouse gas [e.g., $CO_{2,}$ from the burning of fossil fuel] concentrations" (Houghton et al. 2001). Global temperatures (and globally-averaged surface temperatures) are projected to increase another 1.4 to 5.8ºC over the next century—a rate probably unprecedented over the last 10,000 years (Houghton et al. 2001). This is expected to have profound effects on weather and climate.

The last several decades in the Sierra Nevada were among the warmest of the last millennium (Graumlich 1993). Recent simulations of climate change models suggest that by the years 2050 to 2100, average annual temperature in the Sierra Nevada could increase by as much as 3.8º C (Snyder et al. 2002)—the equivalent of about an 800 m upward displacement in climatic zones. Average temperatures in May could increase by 9º C.

Paleoecological records show the early and middle Holocene (ca. 10,000 to 4,500 years ago) was a period of generally higher global summer temperatures (perhaps by 2º C) and prolonged summer drought in California. During this period, fire regimes and plant community composition of Sierra Nevada forests differed from those of today (including some species combinations that no longer exist) (Anderson 1990, Anderson and Smith 1991, Anderson 1994, Anderson and Smith 1994, 1997). For example, early holocene forests (growing on sites that presently support giant sequoia groves) were much more heavily dominated by pines, including lodgepole pine, which no longer occurs in sequoia groves (Anderson 1994). Overall, firs were less abundant than today, and giant sequoias were quite rare (Anderson 1994, Anderson and Smith 1994). Mortality could increase among adult trees as a result of drought stress (Dettinger 2005), which would make them more vulnerable to insects, pathogens, and air pollution. Although the past is an imperfect analog of the future, these and other paleoecological records indicate climatic change smaller than, or comparable to, those projected for the next century could profoundly alter Sierra Nevada ecosystems.

Phenological studies indicated that in much of the West, lilacs and honeysuckles are responding to the warming trend by blooming and leafing out earlier (Cayan et al. 2001). Human-influenced temperature patterns are significantly associated with discernible changes in plant and animal (invertebrate, bird, amphibian, tree, shrub) phenological traits (Root et al. 2005).

Researchers predict that even a relatively modest mean temperature increase (2.5 °C) would significantly alter precipitation, snow pack, surface water dynamics (e.g., flow), and hydrologic processes. The most pronounced changes would probably be earlier snowmelt runoff and reduced summer base flows and soil moisture (Dettinger et al. 2004, Dettinger 2005), a lower snowpack volume at mid-elevations (Knowles and Cayan 2001), and increased winter and spring flooding (Dettinger et al. 2004). Two climate models predict significant reductions in Sierra Nevada snowpack by the year 2100: one model predicts 30 –70% reduction, the other a 73 – 90% reduction (Hayhoe et al. 2004).

Flows in many western streams begin a week to almost three weeks earlier than they did in the mid 20th century (Cayan et al. 2001, Dettinger 2005). There is also a trend towards slightly later precipitation (Dettinger 2005). Observed stream flow timing and winter-spring warming trends are consistent with current projections of how greenhouse effects may influence western climates and hydrology. Changes in precipitation type and timing may result in longer and drier summers, i.e., less water available during the months when it is most needed (Dettinger 2005). Glacial extent in the Sierra Nevada has declined markedly in the past several decades (Basagic, in progress).

Changes in Sierra Nevada climate related to precipitation *quantity* (e.g., snowpack) are less certain (Howat and Tulaczyk 2005). If current trends continue, researchers predict that natural reservoirs provided by snowpack will become progressively less useful for water resources management. In addition, flood risk may change in unpredictable ways and Sierra Nevada ecosystems may experience increasingly severe summer-drought conditions (Dettinger 2005, Dettinger et al. 2005, Mote et al. 2005). Prolonged summer drought alters natural fire regime and would increase the potential for high-severity wildfires and further threaten water quality.

Global warming is likely to shift habitats to higher elevations. Some organisms with limited mobility or specific habitat needs (e.g., amphibians) may not be able to move or survive such habitat shifts and could be locally extirpated. Consequently, species diversity may decline. Some habitats (e.g., high alpine) may shrink dramatically or disappear entirely, leading to irreversible loss of some species (e.g., Clark's Nutcracker) Two climate models predict significant reductions in Sierra Nevada alpine/subalpine forest by the year 2100: one model predicts 50–75% reduction, the other a 75–90% reduction (Hayhoe et al. 2004).

The atmospheric concentration of carbon dioxide (CO_2) has increased by 31% since 1750. The present CO_2 concentration has not been exceeded during the past 420,000 years and likely not during the past 20 million years; the current rate of increase is unprecedented during at least the last 20,000 years. About three-quarters of anthropogenic emission of CO_2 to the atmosphere is due to fossil fuel burning; the rest is predominantly due to land-use change, especially deforestation (IPPC 2001).

It has been argued that the earth's biosphere (primarily, terrestrial biosphere) may have the capacity to sequester much of the increased carbon dioxide (CO_2) in the atmosphere associated with fossil fuel burning. This effect is termed "CO_2 fertilization" because, in the envisioned scenario, higher ambient CO_2 levels in the atmosphere literally fertilize plant growth. Further, because photosynthesis by plants converts CO_2 into oxygen, it has been argued that "CO_2 fertilization" could potentially provide a strong negative feedback on changing CO_2 levels.

However, climatologists contend that as CO_2 concentration of the atmosphere increases, ocean and land will take up a decreasing fraction of anthropogenic CO2 emissions. The net effect of land and ocean climate feedbacks as indicated by models will further increase projected atmospheric CO_2 concentrations, by reducing both the ocean and land uptake of CO_2 (IPCC 2001).

Global climate change is also likely to exacerbate three other systemic stressors: altered fire regime, air pollution, and non-native invasive species. Some models predict future climate change will be accompanied by increased lightning strikes at latitudes spanned by the Sierra Nevada (Price and Rind 1991). Compounding the increase in wildfire ignitions, extreme weather conditions such as drought are likely to result in fires burning larger areas, being more severe, and escaping containment more frequently (Torn and Fried 1992, Miller and Urban 1999c). Warm temperatures create the perfect conditions for the production of smog and ground-level ozone. Global warming is therefore likely to make air pollution problems worse. A warmer climate would create conditions that would allow the expansion of species better adapted to such conditions.

1.8.3 Altered Fire Regimes

From the late 1890s through 1960s, Sierra Nevada park and national forest personnel attempted to suppress all fires, and these efforts were mostly successful. Consequently, numerous ecosystems that had evolved with frequent fires have since experienced prolonged periods without fire (Swetnam et al. 1992, Swetnam 1993, Caprio and Graber 2000, Caprio et al. 2002, Caprio and Lineback 2002).

Change in fire regime has modified ecosystems. In foothill grasslands for example, lack of fire encourages dominance by non-native invasive grasses (Parsons and Stohlgren 1989). Reproduction of shade-intolerant species (e.g., giant sequoia) has been reduced (Harvey et al. 1980, Stephenson 1994). More land is dominated by dense, intermediate-aged forest patches, and less by young patches (Bonnicksen and Stone 1978, Vankat and

Major 1978, Bonnicksen and Stone 1982, Stephenson 1987). Forests are denser, dominated by shade-tolerant species, and shrubs and herbaceous plants may be less abundant (Kilgore and Biswell 1971, Harvey et al. 1980). A buildup of surface fuels has accumulated (Agee et al. 1978, van Wagtendonk 1985) and increasing numbers of small trees have created "ladder fuels", which carry fire into mature tree crowns (Kilgore and Sando 1975, Parsons and DeBenedetti 1979). These changes have led to a higher risk of high-severity wildfires than was present before European settlement and fire suppression activities (Kilgore and Sando 1975, Vankat 1977, Stephens 1995, Stephens 1998).

Lack of fire can affect water resources by reducing stream flows, altering biogeochemical cycling, and decreasing nutrient inputs to aquatic systems (Chorover et al. 1994, Williams and Melack 1997b, Hauer and Spencer 1998, Moore 2000). Less frequent but higher severity wildfires can also impair water resources, resulting in loss of vegetation cover, litter, and organic matter. The formation of these water repellant soil layers can affect evapotranspiration, infiltration, and snowmelt patterns (Helvey 1980, Inbar and Wittenberg 1998, DeBano 2000, Huffman et al. 2001). Potential impacts include increased flooding, erosion, sediment input, water temperatures, and nutrient and metal concentrations (Tiedemann et al. 1978, Helvey 1980, Riggan et al. 1994, Mac Donald and Stednick 2003, Heard 2005).

Lack of fire has reduced habitat (and food) critical for some wildlife species. Number and extent of forest openings have been reduced, which in turn has reduced key herbaceous and shrub species (e.g., nitrogen fixers such as *Ceanothus*) (Bonnicksen and Stone 1982). Wildlife that require these plants, such as deer, now have less habitat available.

In 1968 (Sequoia & Kings Canyon) and 1970 (Yosemite), NPS staff began prescribed burning. After more than 30 years of prescribed fires, significant progress has been made, although park efforts are far from restoring natural fire regimes at the landscape level (e.g., (Caprio and Graber 2000, National Park Service 2004).

1.8.4 Non-native Invasive Species

1.8.4.1 Plants

Some of the most widespread invasive grasses first arrived in California during the 16th century as propagules hitchhiking on explorers; their spread was subsequently exacerbated by grazing, drought, and burning by Native Americans (Hendry 1934, Heady et al. 1992).

Numerous invasive vascular plant species are present in Sierra Nevada parks. Despite management efforts, many are spreading and new invasions continue: at least 180 species now occur in Yosemite, 200 in Sequoia and Kings Canyon, and eight in Devils Postpile.

Herbaceous biomass of foothill grasslands in Sequoia is 99% invasive species (Parsons and Stohlgren 1989), and altered fire regime (i.e., a particular fire frequency, intensity, or seasonal distribution) may be one of the reasons (Parsons and Stohlgren 1989). Fire suppression has likely inhibited plant invasion into montane landscapes because closed-canopy forests are not generally favorable sites for invasive plants. However, reintroduction of fire onto the landscape may promote establishment of invasive species, particularly in resultant light gaps or areas of high fire severity (Keeley 2001). Because plant species evolve–not in association with fire per se–but within a particular fire regime, some highly fire-adapted plant communities (e.g., chapparal) may be vulnerable to invasive competition (Keeley 2001). Also, the invasion process is affected by (1) the extent to which fires and fire management practices encourage establishment and spread, and (2) the degree to which such practices inhibit or reverse the invasion process (Keeley 2001). Concomitantly, the presence of invasive plant can lead to altered fire regimes, including increased fire frequency (Keeley 2001).

Invasive plants can severely alter ecosystems. They can alter soil water dynamics, thereby stressing native species and perhaps increasing the potential for invasion by noxious species such as yellow star-thistle (Gerlach 2004). Parts of Sequoia National Park that have been severely grazed by cattle (trespassing) now harbor numerous invasive species.

1.8.4.2 Animals

At least 30 invasive vertebrate species have been reported in Sequoia and Kings Canyon, and 21 have been reported in Yosemite (NPSpecies Database https://science1.nature.nps.gov/npspecies/). Many of these species (e.g., trout, bullfrog) are of concern to management because they may have deleterious effects on native wildlife populations. The widespread introduction of brown, rainbow, and brook trout into high elevation lakes and streams has altered ecosystems, which were naturally without fish. Introduced fish and chytrid fungus are suspected of being leading factors in declines of native amphibian species in the Sierra Nevada, including the precipitous decline of the mountain yellow-legged frog (Bradford 1989, Bradford et al. 1993, Knapp and Matthews 2000, Rachowicz and Vredenburg 2004, Rachowicz et al. In press). Bullfrogs are voracious predators, and carriers of chytrid fungus. The full impact of bullfrogs on native species in the parks is unknown, but extirpation of California red-legged frog (federally threatened) from Yosemite is attributed to bullfrog presence (S. Thompson, Wildlife Biologist, Yosemite, pers. comm.). Domestic animal species (e.g., free-ranging house and feral cats) consume native species and compete with native wildlife for resources.

1.8.5 Air Pollution: Air Contaminants and Atmospheric Deposition

The southern and central Sierra Nevada are subject to some of the worst air quality in the United States (Peterson and Arbaugh 1992, Cahill et al. 1996), particularly during the summer months. The San Joaquin Valley, west of the Sierra Nevada parks, is a trap for air pollutants originating in the valley as well as pollutants from cities along the central California coast that are carried in on prevailing winds. Southward-flowing air currents enter California at the San Francisco Bay and move through the valley until they reach the mountains at the southern end of the basin, causing an eddy to form in the vicinity of Visalia and Fresno, just west of the southern Sierra Nevada (Lin and Jao 1995) (Figure 1-11). Thermal inversions frequently trap air over the valley at night during the summertime. Airborne pollutants are then transported into the mountains when this air rises during the day. As a result, Sequoia and Kings Canyon have some of the worst air quality found in any NPS unit in the country (Bradford and Gordon 1992, Cahill et al. 1996). Yosemite and Devils Postpile are also impacted, but to a lesser degree.

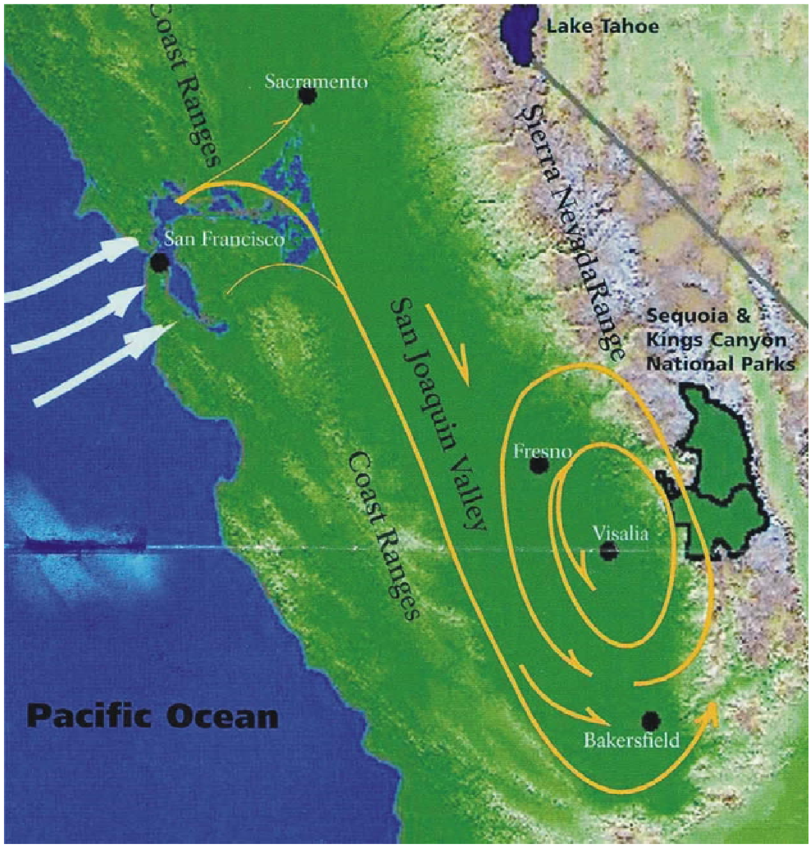


Figure 1-11. Air currents in the San Joaquin Valley, known as the Fresno eddy.

One of the most damaging air pollutants is ozone. Research suggests chronic ozone pollution can lead to shifts in forest structure and composition (Miller 1973). If current ozone concentrations remain relatively constant, or increase, they may affect the genetic composition of pine and sequoia seedling populations and contribute to increased susceptibility to fatal insect attacks, death rates, and decreased recruitment (Miller 1973, Ferrell 1996, Miller 1996). The effects of chronic ozone pollution on other species are not yet known.

There are resultant biological effects of nutrient deposition on aquatic and terrestrial ecosystems, and this enrichment can have considerable effects on sensitive organisms or communities (e.g., lichens and phytoplankton)—even at very low levels of atmospheric deposition (Fenn et al. 2003).

High-elevation aquatic ecosystems in the Sierra Nevada are particularly sensitive to change from atmospheric deposition because the waters are oligotrophic and have a low buffering capacity. In Yosemite, correlations between higher nitrate concentrations in sensitive surface waters and areas of higher nitrogen deposition have been observed (D. Clow, Hydrologist, USGS, pers. comm.). In contrast, decreased exports in dissolved nitrogen were observed in Emerald Lake in Sequoia.National Park. The decrease was attributed to increased phosphorus inputs that caused a switch from a lake dominated by phosphorus limitation to one dominated by nitrogen limitation. Sickman et al. (2003) described two trends in nitrate concentrations in Emerald Lake. During snowmelt, nitrate pulses (i.e., peak values during April) were related to snowpack depth–the deeper the snowpack the greater the nitrate pulse. There is little variation in precipitation concentrations, therefore, the quantity of precipitation (i.e. snowpack depth) is the determining factor.

The second pattern, and the one most relevant to phytoplankton, is a decline in summer/autumn lake nitrate concentrations to zero between the 1980s and 1990s. This late season decline occurred despite the fact that N deposition did not decrease. Instead, increased phosphorus loading allowed the phytoplankton to fully utilize nitrate during the summer/autumn seasons, driving them into a N-limited trophic state. The cause of increased phosphorus loading is unknown, but inputs from atmospheric deposition, soils, and, sediments are likely reasons and the subject of ongoing research.

Mid-elevation, mixed-conifer watersheds in Sequoia's Giant Forest have shown net retention of nitrogen, with stream concentrations often below detection limits (Williams and Melack 1997a). Giant sequoia forests are particularly effective at immobilizing nitrogen and reducing leaching losses; they may be adapted to even more nutrient poor environments than other coniferous ecosystems (Stohlgren 1988).

The consequences of increased nitrogen deposition and retention on terrestrial plant communities in the Sierra Nevada are unknown, but greater foliar biomass production, resulting in enhanced litter accumulation on the forest floor (fuel) and in aboveground biomass (stand densification), may increase the risk of severe fire damage (Fenn et al. 2003). nitrogen pollutants are likely to be important in causing changes in lichen communities—e.g., shifts to nitrophilous species or changes in abundance (Nash and Sigal 1999). Increased levels of soil nitrogen caused by atmospheric nitrogen deposition can increase the dominance of non-native invasive plants and decrease diversity of native plant communities (Vitousek and Howarth 1991, Vitousek et al. 1997). Enhanced growth of invasive species from increased nitrogen has been observed in coastal sage scrub of Southern California, and is implicated in exacerbating invasion of Mediterranean nonnative grasses (Allen et al. 1988). Changes in the alpine plant community of the Rocky Mountains from nitrogen deposition have been observed (Bowman 2000).

With continued urbanization of California's Central Valley, with increasing livestock operations, and with the possibility of transpacific N transport from Asia, it is probable that N deposition and its ecosystem effects in the High Sierra will increase in the next several decades (Fenn et al. 2003).

High elevation lakes and streams in the parks are very dilute and sensitive to change from atmospheric deposition of nutrients, toxic substances, and acids. While chronic acidification is currently not a problem, episodic depression of acid-neutralizing capacity occurs during snowmelt (Melack and Sickman 1995, Melack et al. 1998) and episodic acidification occurs during what are known as "dirty rainstorms", i.e., rainstorms of summer and early fall (Stohlgren and Parsons 1987). If acid deposition increases–which is likely due to rapid population growth in the San Joaquin Valley–episodic acidification will become more frequent and may alter aquatic communities. Recent research suggests Sierra Nevada waters may be fairly resilient and able to buffer current and potentially increased inputs (Leydecker et al. 1999). The actual threat to water quality posed by episodic acidification, however, is unknown.

Sequoia, Kings Canyon, and Yosemite are downwind of one of the most productive agricultural areas in the world, the San Joaquin Valley. Every year, millions of pounds of pesticides (net weight of active ingredient) are applied to crops — 9,872,707 pounds in 2003 alone (Pesticide Use Database, managed by California Department of Pesticide Regulation, http://www.cdpr.ca.gov/). Pesticides volatilize, i.e., become suspended in the atmosphere as particulate matter (atmospheric contaminants), then drift into the parks on prevailing winds. Organophosphates have been found in precipitation up to an elevation of 1,920 meters in Sequoia (Zabik and Seiber 1993). Some synthetic chemicals are endocrine disruptors (hormonal mimics) in concentrations of parts per trillion, potentially leading to altered wildlife reproductive capacity, longevity, behavior, and cancer and mutations (Colburn et al. 1996). Synthetic chemical drift also may play a role in decline of mountain yellow-legged frogs and other amphibians in the Sierra Nevada (Sparling et al. 2001, Davidson and Shaffer 2002). While there is correlation between ecosystem effects and synthetic chemical presence, the mechanism for specific pesticide effects has not been established.

1.8.6 Habitat Fragmentation and Human Use

Sierra Nevada parks have the potential to become functional biological islands due to future human population growth and increases in amounts and types of development on adjacent lands. Population growth for the Sierra bioregion is forecasted to increase by over 50 percent in the next 20 years, from 717,400 in 1990 to 1,110,200 by 2020 (Fire and Resource Assessment Program 1997). This will pose increasing challenges for preserving park ecosystems and biodiversity. Several species already have disappeared from the parks (e.g., grizzly bear, California Condor, California red-legged frog), and others survive in greatly reduced numbers (e.g., mountain yellow-legged frog, Yosemite Toad, Western pond turtle, Willow Flycatcher) (NPSpecies Database https://science1.nature.nps.gov/npspecies/). These losses are partly due to habitat loss on adjacent lands, with park habitat being insufficient to support local populations over the long term (Graber 1996). This problem is particularly serious for foothill species, including seasonally resident species, because most land adjacent to undisturbed foothill habitat is primarily privately owned and subject to development, grazing, agriculture, water diversions, altered fire regime, and non-native invasive species (including free-ranging pets and feral animals).

Coniferous forests on lands adjacent to park boundaries are mostly within national forests, where forest ecosystems have been altered by timber harvest, grazing, water diversions, non-native invasive species, and altered fire regimes. Declines of forest mesocarnivores (e.g., wolverine, fisher, red fox), bats, and owl species are attributed to forest structure changes in the region (DeSante 1995, Graber 1996).

Livestock grazing on other non-park public land east of the Sierra Nevada crest has prevented re-establishment of healthy metapopulations of Sierra Nevada bighorn sheep (*Ovis canadensis* ssp. *nova*) within the parks, leading to their endangerment (Wehausen 2003).

Animals that routinely travel outside park boundaries (e.g., mule deer, black bear, and band-tailed pigeon) thereby become part of hunted populations. Such management activities outside parks are likely to affect age structure and abundance of species within park boundaries. Non-hunted park populations are a likely reservoir for hunted and less dense populations outside the parks.

Concomitant with population growth are changes in wilderness values such as dark night sky and the natural soundscape. Dark night sky benefits many living things, and light pollution is rapidly eroding the unspoiled view of stars. Natural sounds (e.g., morning bird chorus) are integral to the park experience for visitors and essential to the health of ecosystems. Increases in anthropogenic sound such as from airline overflight can disrupt wildlife behavior.

1.9 Approach to Developing a Monitoring Program

Monitoring at large geographic scales presents many challenges, including identifying clear goals and objectives and selecting attributes to monitor based on thorough consideration of existing knowledge of the ecosystem and management needs. Reviews of large-scale monitoring plans have identified failure in both content and process (Manley et al. 2000). Frequently, monitoring efforts have been based on relatively poor ecological theory, little consideration of cause-effect relationships, and inadequate or uninformed approaches to selecting, justifying, and evaluating the specific indicators to monitor (National Research Council 1995, Bricker and Ruggiero 1998, Noon et al. 1999).

The National Park Service Washington Support Office (WASO) has recommended a 3-phase approach to developing a monitoring program to help ensure that all networks invest time upfront in effective planning and design for vital signs monitoring. Summarized briefly, these phases are

- Phase I: overview of the understanding of ecosystem(s) using conceptual models, literature reviews, and local knowledge; defining goals and objectives for the monitoring program; beginning the process of identifying, documenting, evaluating and synthesizing existing data; identifying the important resource management and scientific issues for the parks; and completing other background work that must be done before initial prioritization and selection of vital signs.
- Phase II: process for identification, prioritization, and selection of vital signs; reduced list of vital signs that the network will pursue for protocol development and list of vital signs being monitored through other programs, agencies, and funding sources.
- Phase III: sample design; sampling protocols; plan for data management, analysis, and reporting; overview of program administration and implementation; budget and schedule.

Each phase builds upon the previous one, so that the final plan incorporates revisions and responses to peer reviews done for all phases. In addition to a well-defined planning process, the NPS vital signs monitoring program also includes formation of a Board of Directors in each network that reviews program progress and a Science or Technical Committee that works with the Inventory & Monitoring staff to develop and implement the program.

1.9.1 Vital Signs Monitoring

The Sierra Nevada Network received funding for biological inventories from fiscal year (FY) 2001 through 2003, vital signs monitoring startup funds in FY2003, and full vital signs and water quality funds in FY2004. The Biological Inventory Plan (National Park Service 2001b) was completed by a Sierra Nevada Network working group of NPS and US Geologic Survey (USGS) staff members from all network parks. The timeline for inventories and Phases I, II, and III of vital signs planning is summarized in Table 1-5.

The network and park staffs felt it was important that each park have an individual workshop prior to network-level scoping so that individual park resource issues and monitoring needs could be addressed and documented in detail. The scoping workshop for Sequoia and Kings Canyon National Parks was held in April 1999 in conjunction with a Resource Management Plan scoping workshop (Mutch and Lineback 2001, Mutch 2002, Mutch and Thompson 2003). Devils Postpile National Monument and Yosemite National Park vital signs workshops were held in April 2002 (Mutch and Lineback 2001, Mutch 2002, Mutch and Thompson 2003).

In general, the purpose of park vital signs workshops was to bring together people with varied specialized knowledge of the Sierra Nevada ecosystem to identify ecosystem attributes and processes indicative of ecosystem change for Sierra Nevada parks and evaluate these indicators against specific ranking criteria. Workshop participants were also asked to add to a list of stressors (prepared by USGS-BRD and NPS staffs) and identify any stressors known to be associated with vital signs identified in work groups. The objective of the workshops was to identify and prioritize ecosystem components and processes that, when monitored, would allow park managers—in a scientifically credible, quantifiable, legally defensible, and economical manner—to quickly and accurately detect changes in ecosystem integrity.

Vital signs generated at park-level workshops were summarized and consolidated by the Science Committee (described below) for network-level prioritization through a series of meetings and discussions. Network prioritization occurred at a workshop with SIEN NPS and USGS staff in March 2005, when staff again reduced the number of vital signs. From these, the final group of vital signs were ultimately selected (Table 1-6) through a series of subsequent Science Committee meetings.

Staffing of the network started with a temporary, then term, Network Coordinator in December 2000 and October 2001, respectively. The Network Coordinator (permanent) was hired in November 2003; subsequent staff additions included the following

- term Biological Technician in October 2003
- permanent Data Specialist in April 2004
- term Physical Scientist in July 2004
- term Ecologist in October 2004 (replacing term Biological Technician)
- term, part-time Administrative Assistant in May 2006.

Table 1-5. Timeline for the Sierra Nevada Network to do inventories and complete planning process for vital signs monitoring.

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007
Data documentation and summaries									
Inventories to support monitoring									
Individual park scoping workshops	**SEKI**			**DEPO YOSE**					
Conceptual Modeling									
Network workshops Vital sign prioritization and selection									
Data Management Plan									
Protocol Development, Monitoring Design									
Monitoring Plan Due Dates-phases 1, 2, 3							**Phase 1 Oct 04**	**Phase 2 Oct 05**	**Phase 3 Oct 07**

The term positions are being hired to support the planning process. When vital signs are selected, the Network will re-evaluate needs for additional permanent or term staffing.

The Network's first charter was established in February 2002 (see Table 1-6 for timeline of events). The Board of Directors includes

- Superintendents from Devils Postpile, Sequoia and Kings Canyon and Yosemite (voting)
- Resource Management Division Chiefs in Sequoia and Kings Canyon, and Yosemite (voting)
- Science Adviser from Sequoia and Kings Canyon (voting)
- Pacific West Region I&M Coordinator (non-voting)
- Deputy Regional Director (non-voting)
- Network Coordinator (non-voting, and staff to the Board)

The twelve-member Science Committee consists of two Resources Management staff members; one USGS scientist from both Sequoia and Kings Canyon and from Yosemite; the Science Adviser; Director of the UC Merced Sierra Nevada Research Institute; and the Network coordinator (who chairs the committed), data specialist, physical scientist, and ecologist.

Table 1-6. Timeline of events in the organization of the Sierra Nevada Network and monitoring planning.

Year and Month		Event
2000	December	Temporary Network Coordinator entered on duty
2001	January	Biological Inventory Plan approved
	October	Term Network Coordinator entered on duty
	December	SEKI 1999 vital signs scoping workshop report completed
2002	February	Network charter approved and signed by Superintendents
	April	Park-level vital signs scoping workshops held for Devils Postpile and Yosemite
	September	First Board of Directors meeting held
	November	First Science Committee meeting held
	December	DEPO and YOSE vital signs workshop reports completed
2003	Sept-Dec	Data mining and documentation
	October	Term Biological Technician entered on duty
	November	Permanent Network Coordinator entered on duty
	November	First (of a series) conceptual modeling workshop with Science Committee and cooperator
2004	Jan-June	Series of Science Committee planning meetings and conceptual modeling workshops; Data mining and documentation
	April	Permanent Data Specialist entered on duty
	June-August	Prepared Phase I report draft
	July	Term Physical Scientist entered on duty (see § 1.4.2 below)
	October	Term Ecologist enters on duty; Biological Technician position vacated
2005	March	Network vital signs prioritization workshop
	April-June	Science Committee meetings to select vital signs, prioritize pilot studies
	June-July	Phase II report drafted
	Oct-Sept	Data mining and documentation, preparation of data for NPSpecies; Natural Resource Database Template Committee database revisions
2006	Dec-Sept	Protocol development in progress
	May	Administrative Assistant enters on duty
	Sept	Draft Phase 3

1.9.2 Water Resources Monitoring

The Natural Resource Challenge (NRC), in addition to funding vital signs monitoring, includes separate funding earmarked for long-term water quality monitoring. The purpose of the funding is to track attainment of the service-wide water quality strategic goal—'to improve the quality of impaired waters and to maintain the quality of pristine waters'. Although the NRC allocates separate funding, it was anticipated that there would be full integration of water quality and vital signs monitoring (Miller 2000). In areas where water resources are identified as a high priority, water quality monitoring may be expanded using the core vital signs funding. I&M networks have the option of producing a separate water quality monitoring plan, or a single, integrated vital signs-water quality monitoring plan.

Sierra Nevada Network parks do not contain impaired waters; the parks contain over 6,000 lakes and thousands of kilometers of rivers and streams, and these have some of the highest water quality in the Sierra Nevada. The Network determined that integrating the water resources monitoring with vital signs monitoring was the most effective way to monitor and protect our parks' waters. Monitoring of other ecosystem components will enhance water quality monitoring efforts. For example, forest demography monitoring can help explain trends in hydrology and water quality related to changes in evapotranspiration caused by changes in tree growth and mortality. In turn, water quantity and quality are critical components of the Sierra Nevada parks' ecosystems and good indicators of aquatic and terrestrial ecosystem condition. The largest threats to our waters—increasing nutrient and pesticide deposition, climate change, and altered fire regimes—are also major threats to the larger Sierra Nevada ecosystem (*See section 1.7 Sierra Nevada Ecosystem Stressors).*

Since water resources are critical in the Sierra Nevada, the Network has emphasized the development of water resources monitoring. Some of the main steps the Network has taken towards development of an integrated water resources monitoring program are

- ***Evaluating Existing Water Resources Information in Sierra Nevada Network Parks***: In November 2003, the Network established a Great Basin CESU Cooperative Agreement with Colorado State University to summarize existing water resources information for Sierra Nevada parks. The final products were a literature search compiled in an EndNote database and summary report presented in Appendix D. This report has been expanded throughout 2004 and 2005.
- ***Water quality geo-database***: In spring 2004, the Sierra Nevada Network established an interagency agreement with the U.S. Geological Survey, Water Resources Division, to develop and populate a geo-database with existing water quality data. The database was completed in summer 2005. The database is currently being utilized by network staff to analyze existing water quality data, create maps, and identify information gaps.
- ***Physical scientist***: In July 2004, the Network hired a GS-09 term physical scientist to conduct planning and implementation of the SIEN water quality monitoring program.
- ***Long-term watershed study manuscript***: In 2005, the Network contributed a small amount of funding towards the completion of a manuscript synthesizing almost two decades of research in Tharp's and Log watersheds. This was a paired watershed study in the Giant Forest area of Sequoia National Park. Researchers studied biogeochemical processes within these watersheds with a focus on atmospheric deposition and prescribed fires.
- ***Vital signs selection***: Evaluation of water resource indicators has been fully integrated into the larger vital signs' ranking and selection process. In order to gain more information to better evaluate candidate vital signs, the network is funding several projects targeted at indicator and feasibility evaluation and initial protocol development. Specific to water resources, the Network is helping to fund a cooperative NPS-USGS project evaluating the suitability of stream chemistry as an indicator of elevated nitrogen fluxes to high elevation basins.

For more information, refer to SIEN Annual Administrative Report and Work Plans.

1.10 Monitoring Goals, Objectives, and Questions

(adapted from http://science.nature.nps.gov/im/monitor/vsmTG.htm#GoalsObj, and Southwest Alaska Network Monitoring Plan (Bennett et al. 2003), http://www1.nrintra.nps.gov/im/monitor/examples/SWAN_go.pdf)

The overall purpose of natural resource monitoring in parks is to

> *Develop scientifically sound information on the current status and long term trends in the composition, structure, and function of park ecosystems, and to determine how well current management practices are sustaining those ecosystems. Use of monitoring information will increase confidence in management decision-making and improve their ability to manage park resources, while also allowing managers to confront and mitigate threats to the park and operate more effectively in legal and political arenas. To be effective, the monitoring program must be relevant to current management issues as well as anticipate future issues based on current and potential threats to park resources. The program must be scientifically credible, produce data of known quality that are accessible to managers and researchers in a timely manner, and linked explicitly to management decision-making processes.*

All 32 networks within NPS will address the following five service-wide vital signs' monitoring goals in the planning, design, and implementation of integrated natural resources monitoring.

The following goals will guide the emphasis and design of Sierra Nevada Network's monitoring program:

NPS Service wide Vital Signs Monitoring Goals

1. Determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.
2. Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.
3. Provide data to better understand the dynamic nature and condition of park ecosystems, and provide reference points for comparisons with other, altered environments.
4. Provide data to meet certain legal and congressional mandates related to natural resource protection and visitor enjoyment.
5. Provide a means of measuring progress toward performance goals.

The Sierra Nevada Network parks protect large segments of wilderness from direct human impacts such as logging, commercial development, and cattle grazing. However, due to the geographic proximity of the Sierra Nevada to large population centers and highly productive agricultural lands, the parks are vulnerable to multiple stressors that are not excluded by land management boundaries drawn on a map. The stressors of primary importance to the Sierra Nevada (SNEP 1996a), section 1.8) form a major portion of the framework for our thinking about vital signs monitoring. Our monitoring objectives reflect our dual interest in understanding the underlying dynamics and components of the ecosystem and the effects of major stressors upon that system.

Development of monitoring objectives and questions has been an iterative process, with the Science Committee developing the first set of monitoring objectives by consolidating monitoring questions developed at park-level vital signs workshops. The objectives below have been modified through development and revision of conceptual models and refining the focus of our monitoring questions through a network-level vital signs workshop and subsequent Science Committee and smaller work group meetings. Monitoring questions will continue to be modified, removed, or added as the planning process proceeds.

1.10.1 Objectives

Objective 1: Understand the natural range of variation in annual and seasonal weather patterns, long-term trends in climate, and effects of global climate change on hydrologic regimes and biological processes.

- How do patterns of precipitation (type, duration, and intensity), seasonal temperature fluctuations, and other meteorological variables (solar radiation, wind speed and direction, relative humidity) vary spatially and temporally?
- Can changes in general and seasonal trends in temperature (warming or cooling) and precipitation (increased or decreased) be detected?
- How are these trends affecting regional hydrologic regimes (snowpack depth, snow water equivalent, snowmelt, glacial extent, frequency, and intensity of flood events and volume and timing of river and stream flows)?
- How are climate trends affecting the timing of key phenological events in plants and animals? Is the timing of onset and cessation of earlywood and latewood growth changing?
- How are the dynamics (establishment, growth, and death rates) of tree populations changing, and are any observed changes correlated with climate change?
- How resistant to change are Siera Nevada ecosystems? What are the alternative stable states of Sierra Nevada ecosystems?

Objective 2: Understand patterns of spatial and temporal variation in fire regime characteristics and relationships to changes in climate and vegetation.

- How does fire regime (frequency, severity, and spatial extent) change in response to variation in climate and vegetation?
- Are changes in vegetation composition and stand structure, which are driven by global change, causing altered fire regimes in the Sierra Nevada?

Objective 3: Understand patterns of temporal and spatial distribution of air-borne pollutants, and their effects on aquatic and terrestrial systems.

Ozone

- How do ozone levels vary temporally and spatially and are trends detectable in these patterns?
- How are increasing levels of ozone affecting vegetation? Are concomitant changes in fatal insect attacks or tree population dynamics (recruitment and death rates) occurring, and are any observed changes correlated with ozone levels?

Air Contaminants

- How do concentrations of persistent organic pollutants (POPs) vary spatially and temporally in atmospheric, aquatic, and terrestrial systems?
- Are the concentrations of important POPs and other toxins (e.g., metals) increasing in the tissues of plants and animals? Are these changes associated with detectable changes in reproduction rate, longevity, genetic mutations, or other biological processes?

Atmospheric deposition

- How do depositional patterns of important nutrients (principally nitrogen and phosphorus compounds), hydrogen, and other major cations/anions vary along elevation gradients, in aquatic and terrestrial systems, and through time?
- How are patterns of nitrogen cycling changing?
- Are episodic acidification events increasing and are these events altering aquatic communities?

Objective 4: Understand natural patterns of variation in hydrology and how these processes respond to changes in climate and fire regime.

- How are stream and river discharge rates and the timing and magnitude of peak flows changing?
- How are water dynamics changing in response to climate and fire regimes?
- How are surface water volumes changing in lakes and wetlands?
- How are the height and supply of shallow groundwater and flow regimes changing in wet meadows and other wetlands?
- How are changes in hydrology affecting the dynamics and characteristics of stream/river channel morphology?

Objective 5: Monitor water quality and the response of native aquatic biota to changes in chemical and physical properties of aquatic systems.

- How does water chemistry (concentrations and fluxes) vary spatially and temporally across network parks?
- How is water quality changing with respect to water quality standards?
- How are sediment loads (concentration, turbidity) and sediment transport rates changing through time?
- How are toxin species and concentrations changing in network waters, animal tissue, and aquatic and riparian vegetation?

- How are plants and animals responding to changes in nutrient concentrations, heavy metals and toxins, sediment loads, and water temperature? What effects are these responses having on aquatic food chains and biological diversity?

Objective 6: Understand compositional and structural patterns of plant communities and their distribution on the landscape.

- What is the baseline spatial-temporal variation in community composition and relative abundance of native and non-native perennial plant species?
- What is the natural variation in community composition and relative abundance of perennial plant species?
- What non-native plant species have the potential to invade park ecosystems in the near future and how can we ensure early detection of their presence?

Objective 7: Document rates and types of change in plant communities in response to environmental factors and human effects.

- How do the structure, composition, and distribution of plant communities change in response to variation in climate, fire regime, and human use?
- How are abundance and distribution of non-native plant species changing, and what impacts are these having on native plant communities and animals?
- How are wetlands and wet meadows changing in size, species composition, and productivity in relation to changes in human use (such as stock grazing) and climate? How are associated animal communities affected by these changes?
- How is net primary productivity changing in aquatic and terrestrial systems in relation to changes in climate, fire regime, and human use?

Objective 8: Understand the ecological relationships between terrestrial landscape elements and animal distributions.

- How do abundance, distribution, and diversity of animal species (e.g., amphibians, land birds, bats) and communities vary spatially and temporally across park landscapes?
- How does the distribution of cave-adapted organisms change spatially and temporally within and among caves in a watershed?

Objective 9: Document rates and types of change in animal communities.

- How are abundance, diversity, and distribution of animal species (e.g., amphibians, land birds, and bats) and communities changing across network parks in response to changes in vegetation?
- How are avian productivity and survivorship changing?
- Are any new non-native animals establishing in the parks?
- How are the distribution and abundance of native amphibians and aquatic invertebrates changing in the response to the presence of non-native fish?
- How are the distribution and/or relative abundances of large and medium sized carnivores changing in response to changes in land use?

Objective 10: Monitor resources that have been identified as having unique values to the network parks. These resources may or may not be the best indicators of ecosystem condition, but are valued in and of themselves.

Night sky

- How is brightness of the night sky changing because of light intrusion from sources both inside and outside of parks; how is the visibility of stars affected?

Visibility

- How are the sources, amounts, and distribution of particulate matter changing seasonally, annually, and spatially? How is visibility in Class I airsheds affected by these changes?
- Soundscape
- How are natural soundscapes changing because of increasing human activity (car traffic, construction, commercial and military air traffic)?

Objective 11: Monitor trends in the distribution and abundance of focal species.

- How are the distribution and abundance of special status species changing?

1.11 Overview of Past and Present Monitoring

Park-based monitoring projects likely to have the most value to Sierra Nevada Network's vital signs monitoring program are those pertaining to resources that have been identified as potential vital signs, indicators, or measures, and that have formal and well-documented protocols.

These monitoring projects (past and present) are summarized for Sierra Nevada Network parks (Table 1-8, at the end of this chapter). Other short-term monitoring (up to three years) and important baseline inventories that may have value in supporting Sierra Nevada Network's vital signs program are described in detail in Appendix G.

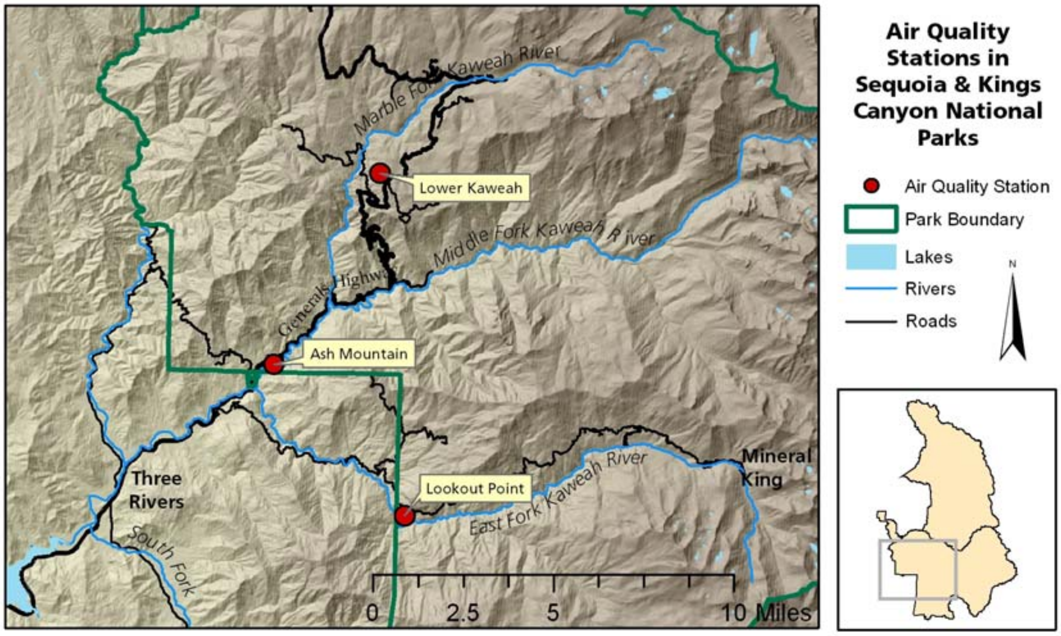
1.11.1 Air

For detailed information on the atmospheric monitoring program in and around SIEN, please see Appendix D.

In the Sierra Nevada Network there are three Class I air sheds (YOSE, SEQU, KICA) and one Class II air shed (DEPO). According to the Clean Air Act and subsequent amendments, federal land mangers have responsibility to protect visibility, flora, fauna, waterbodies, and other resources that may be potentially affected by air pollution.

Class I parks in the SIEN network have a complex air monitoring program (Table 1-7). Supported by the NPS Air Resources Division, these parks are included in several nationwide programs measuring wet and dry deposition, ozone, visibility, mercury, particulate matter, and meteorology.

Both Yosemite and Sequoia and Kings Canyon operate year-round air monitoring stations, some dating back to the early 1980s (Figure 1-12 and Appendix C). Each site is unique in its array of monitoring equipment (inset). Devils Postpile National Monument does not currently conduct air monitoring within the boundaries of the monument.



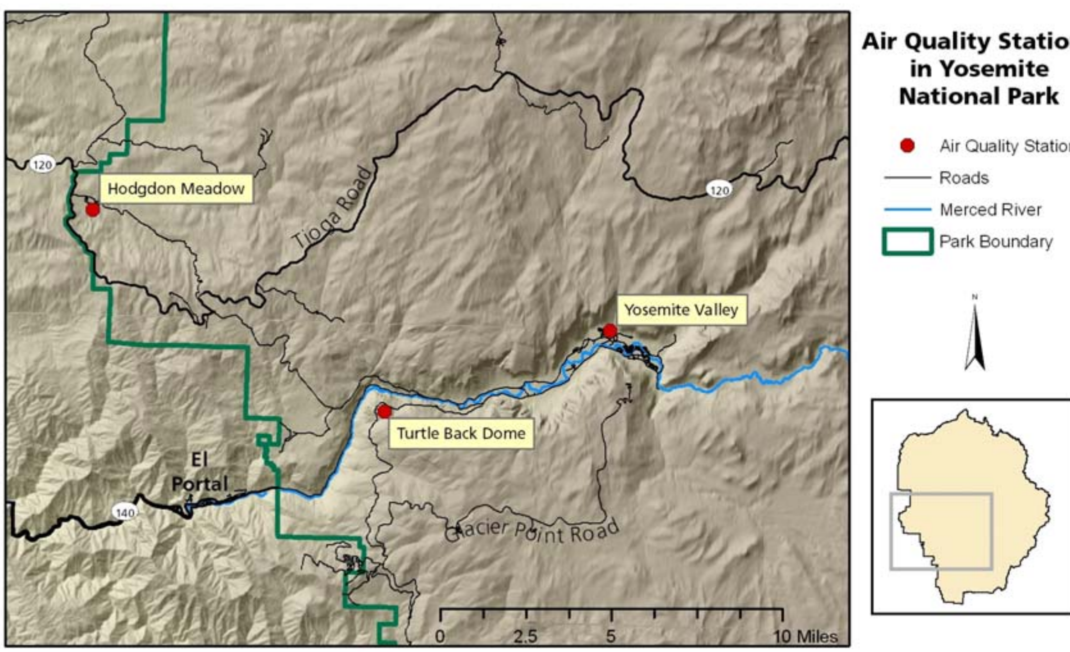


Figure 1-12. Air quality stations in SIEN parks.

Table 1-7. Air quality monitoring sites and variables measured.

Sequoia & Kings Canyon	**Ash Mountain**	Yosemite	**Yosemite Valley**
	Meterology		PM 2.5 and 10
	Ozone		Meteorology
	Particulate Matter		Ozone
	PM 2.5 and 10		NOX
	Lookout Point		Carbon Monoxide
	Meterology		**Turtleback Dome**
	Ozone		Meteorology
	Dry deposition		Ozone
	Lower Kaweah		Visibility
	Meterology		Dry deposition
	Ozone		Particulate Matter
	Wet deposition		Webcam (hyperlink)
	Mercury		**Hodgdon Meadow**
	Webcam		Wet deposition

1.11.2 Wildlife (Terrestrial and Aquatic)

Most long-term monitoring of wildlife (terrestrial and aquatic) has been conducted on bears (interactions/incidents with humans), birds, and a few selected groups and taxa with special status (mountain yellow-legged frog, Sierra Nevada bighorn sheep) (Table 1-8).

Baseline or directed inventories have been conducted on many vertebrate groups (birds, mesocarnivores, bats, salamanders), and special status species (e.g., California Spotted Owl, Great Grey Owl, Western Pond Turtle, Mountain yellow-legged frog).

Invertebrates have generally been under-represented in inventory, monitoring, and other studies in Sierra Nevada Network parks.

1.11.3 Vegetation (Terrestrial)

Sequoia, Kings Canyon and Yosemite National Parks have a rich history of vegetation-related inventories, research, and monitoring projects. Most long-term vegetation monitoring in these parks has been related to measuring effects of resource management programs (especially fire, exotic plant control and restoration), recreation (especially pack stock grazing), and air pollution (described above). The USGS-Biological Resources Division also conducts long-term vegetation monitoring in Sequoia and Kings Canyon and Yosemite: forest demography across elevations is the longest term dataset. Aside from fire-effects plots established in 1992, Devils Postpile has not had staffing or resources to do long-term vegetation monitoring.

All parks have had vegetation inventories done that are of value as baseline data for long-term monitoring. These include vegetation maps, Natural Resource Inventories in the 1990s in Sequoia, Kings Canyon, and Yosemite (Graber et al. 1993), a vascular plant inventory in Devils Postpile (Arnett and Haultain 2004), and rare plant surveys for individual park units (in progress, and Moore 2006).

1.11.4 Fire

Detailed information on fire monitoring can be found in park Fire Management Plans (National Park Service 2003a, 2004).

The parks' fire monitoring programs began in 1982 for Sequoia & Kings Canyon, 1978 for Yosemite and 1992 for Devils Postpile. The programs in Sequoia & Kings Canyon and Yosemite initially focused on monitoring weather and fire behavior, vegetation, and dead and down surface fuels in giant sequoia groves and other early experimental prescribed burns in mixed-conifer forests. Over time, the monitoring programs expanded to other plant communities as the prescribed fire programs progressed. In recent years, Sierra Nevada fire-monitoring programs have broadened to include additional vegetation, wildlife, water, and/or fire regime components. Devils Postpile does not currently have a Fire and Fuels Management Plan (NPS, in progress); however, fire effects monitoring plots were established in association with a 1992 wildfire that burned approximately two-thirds of the monument.

Monitoring environmental and fire condition provides information to guide fire management strategies for both wildland and prescribed fires; such monitoring encompasses a wide variety of fire topics, including

- environmental and fire conditions
- fire effects on vegetation and fuels
- mechanical fuels-treatment monitoring
- fire effects on animals
- fires effects on water
- fire regimes, restoration, baseline fire history

In addition to fire-related monitoring conducted by SIEN park staff, USGS-Western Ecological Research Center staff at both Sequoia and Kings Canyon and Yosemite Field Stations have contributed a huge amount of fire-related monitoring in SIEN parks and the greater Sierra Nevada region. USGS projects in our parks are an integral part of NPS resource management information and decision-making.

1.11.5 Aquatic

For detailed information on the water monitoring program in and around SIEN, please see Appendix D.

In Sequoia and Yosemite National Parks, long-term stream flow monitoring dates back to 1949 and 1918, respectively (Figure 1-13). Sequoia has twelve active gauging stations located in or near the park’s boundary, with periods of record ranging from eight to 54 years. Yosemite has 48 active gaging stations with periods of record ranging from one to 96 years. Devils Postpile and Kings Canyon do not have long-term stream flow records, although a gaging station was recently installed on the Middle Fork of the San Joaquin River in Devils Postpile.

The longest network water quality monitoring site is on the Merced River at Happy Isles in Yosemite. Happy Isles is a USGS Hydrologic Benchmark Network site with water quality data from 1964 to present. In Sequoia National Park, there are four water quality monitoring sites with 15-20 years of data, although only one site is currently monitored. In Devils Postpile, California Department of Fish and Game monitors basic water quality variables (pH, conductivity, temperature, and alkalinity) at eight different sites as part of a statewide fisheries monitoring program (National Park Service 1998).

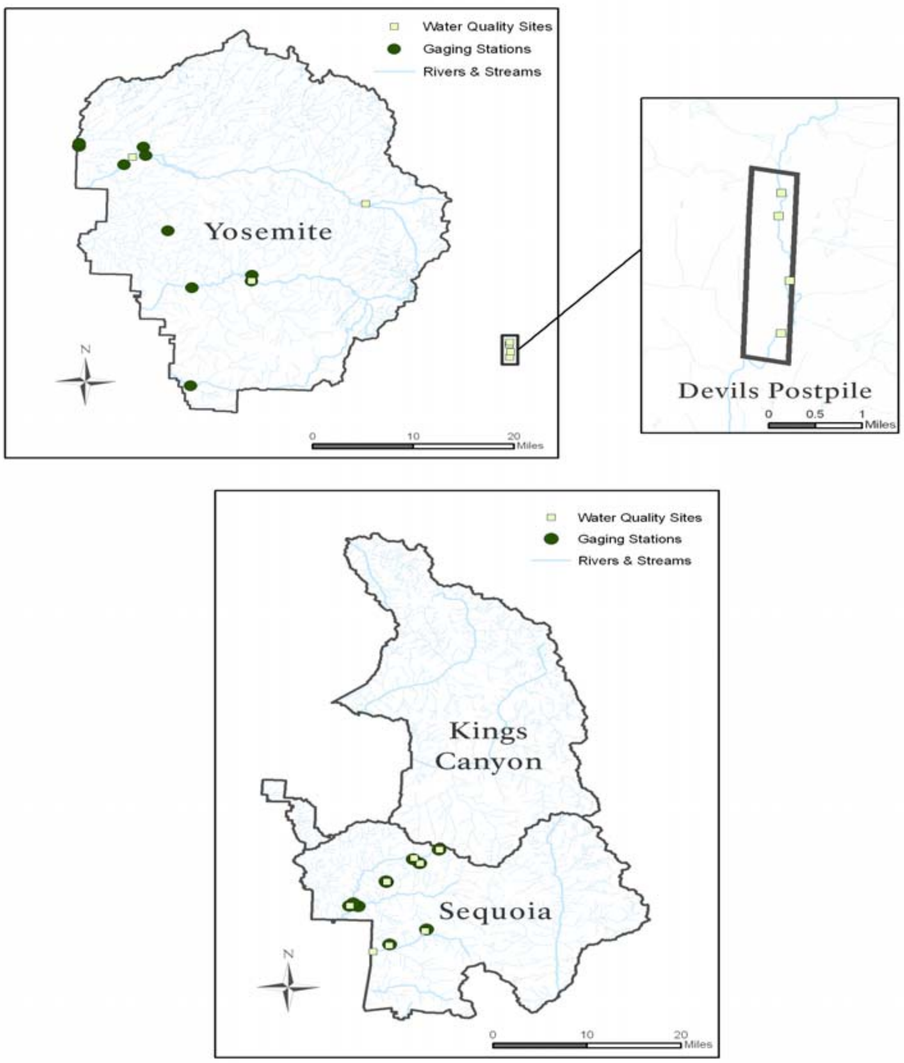


Figure 1-13. Gauging stations and water quality sites with long-term monitoring records.

1.11.6 Geologic and Other Physical Resources

For detailed information on monitoring of geology, geomorphology, physical cave resources and soils, please see Appendix G.

1.11.7 Summary of Monitoring Related to Vital Signs Program

Current or past park-based monitoring projects, which may have the most value to Sierra Nevada Network's vital signs monitoring program, are those projects pertaining to resources that are closely aligned with Network vital signs.

These monitoring projects (past and present) are listed in Table 1-8; each is described in greater detail in Appendix G.

Text and tables describing or summarizing additional short-term monitoring projects ($\leq$3 years) and baseline inventory projects, also with potential value to the vital signs monitoring program (organized by topic and park), are also summarized in Appendix G. Detailed descriptions of the Network's most evolved monitoring programs–air and water– can be found in Appendices C (Air Resources) and D (Water Resources).

Project details (e.g., abstract, purpose) and available metadata (e.g., duration of project, location of data) are described in the Network's data documentation database (originally developed and populated circa 2003). Additions to this database are ongoing.

Table 1-8. Summary of existing monitoring data in Network parks with most value to vital signs program.

Monitoring Category	Description	Network Park: Devils Postpile	Network Park: Sequoia & Kings Canyon	Network Park: Yosemite	Notes
Air	Air Quality (ozone, visibility, precipitation, chemistry)		●	●	Clean Air Act
Meterology/Climate	Meterological Variables (temperature, precipitation, relative humidity, radiation, wind speed and direction)	●	●	●	
	Snow: water equivalent, depth	●	●	●	Water supply: San Joaquin Valley, San Francisco
Water	Stream flow	●	●	●	
	Water Quality		●	●	
Caves	Visitation		●		
	Radon		●		
	Temperature		●		
Geomorphology	River Cross-section			●	
Animal	Wildlife Observation Database	●	●	●	DEPO no formalized system
	Grinnell Survey			●	Resurvey of historic (circa 1917) trans-Sierra transects
	Annual Report			●	
	Mountain Yellow-legged frog		●		As part of non-native fish eradication project
	Western Pond Turtle		●		
	Avian Productivity & Survivorship				MAPS stations
	Breeding Bird Survey		●	●	As part of USGS program
	Christmas Bird Count		●	●	As part of Audubon Society program
	Peregrine Falcon		●	●	As part of federal delisting protocol
	Pacific Fisher, Red Fox, California Wolverine			●	
	Black Bear–Human Interactions		●	●	
	Sierra Nevada Bighorn Sheep		●	●	
	Bats			●	Anabat detectors
	Mule Deer			●	California Department of Fish

		Network Park			
Monitoring Category	**Description**	**Devils Postpile**	**Sequoia & Kings Canyon**	**Yosemite**	**Notes**
					and Game
Animal (cont.)	Little Kern Golden Trout		●		
	Macroinvertebrates			●	Student-science program
	Fire Effects (birds, bark beetle, small mammals)		●		USGS: Fire and Fire Surrogate study
Vegetation	Forest Demography		●	●	USGS
	Ozone effects (*Pinus* spp. and others)	●	●	●	Project FOREST
	Ozone effects (multiple species)		●		USDS Forest Service, Forest Inventory and Analysis plots
	White Pine Blister Rust		●	●	
	Vegetation Change		●		Repeat photography
	Fire: Effects on plant diversity and invasives		●		USGS
Fire: Environmental Conditions	Fire weather		●	●	
	Fire conditions (wildland, prescribed)		●	●	
	Burn severity		●	●	
	Fire behavior		●	●	USGS
	Fuels		●		USGS
	Soils, forest floor		●		USGS
	Pathogens		●		USGS
	Invasive annual grasses		●		USGS
Fire: Effects	Vegetation: pre-burn, post-burn		●	●	No pre-burn data for DEPO
	Repeat Photography	●	●	●	
	Hydrology, Hydrochemistry		●		USGS
Fire: Regime	Fire History	●	●	●	
	Cumulative accomplishments		●		
Mechanical Fuels Treatment	Effects of mechanical thinning		●	●	Including pre- and post-treatment data collection
	Repeat Photography		●	●	

1.11.8 USFS Monitoring Program: Sierra Nevada Forests (1995 to present)

From an initial monitoring plan for California Spotted Owl (circa 1995-1996), the Sierra Nevada US Forest Service (USFS) monitoring program began a broader, more strategic approach (circa 1997). In 1997, a Sierran Province Assessment and Monitoring (SPAM) team was formed and began a five-year planning phase (funding level of $1 million per year). This planning team consisted of 20 biologists.

Similar to SIEN's Phase I planning efforts, SPAM's review and assessment of land management plans on Sierra Nevada forests revealed that not much systematic monitoring was occurring. In addition, no other regional-level ecosystem monitoring programs were in place in other USFS regions.

Over a span of five years (through 2001), SPAM worked to create a cost-effective, science-based strategy for monitoring, and developed an Ecosystem Process Model. Two subsequent initiatives affected this planning endeavor: Sierra Nevada Ecosystem Project (SNEP) completed in 1998 and the Sierra Nevada Framework for Conservation and Collaboration. The SPAM team was commissioned to work on the Framework EIS in 1999.

The Framework identified five key "problem" areas that then became the focus of the monitoring team and their planning efforts

- Old forest ecosystems
- Lower west-side hardwood forests
- Fire and fuels
- Noxious weeds
- Aquatic, riparian ,and meadow systems

In 2001, the Sierra Nevada Forest Plan Amendment was completed, with a description of monitoring issues, questions and needs (www.fs.fed.us/r5/snfpa).

In addition, the monitoring team received $3 million. A lead team of 10 biologists, with 60 temporary biologists, prepared 40 study plans and used a ranking process to prioritize monitoring topics in these plans.

Such monitoring topics could be considered similar to SIEN's vital signs. However, the monitoring objectives, questions, and metrics–and therefore study design and sampling protocols–could be different from SIEN parks' needs and objectives.

From these 40 topics, the following seven were implemented for pilot testing in 2001. Some were never funded, and several others lost funding (as noted in parentheses)

1. Carnivore: focus on fisher, marten
2. Amphibians: focus on Yosemite toad, mountain yellow-legged frog
3. Multi-species
4. Meadows (last funded in 2004)
5. Fire and fuels (last funded in 2004; some work continuing)
6. Noxious weeds (never funded)
7. Old forest and lower west-side hardwoods (last funded in 2004)

Two air quality and one lake chemistry projects were identified in an additional air quality study plan, but no funding was available until circa 2003:

8. Ozone injury to pines (last funded in 2004)
9. Smoke from prescribed burns
10. Lake acidification, from air pollution (last funded in 2004)

Sierra Nevada USFS monitoring goals were to have some (1) general condition information in 5 years, and (2) trend information in 10 years.

SIEN will evaluate USFS' monitoring objectives and protocols, for the topics notedabove, to see where collaboration is feasible and prudent for those projects still being funded (e.g., amphibians), or to see where protocols can be used or adapted (e.g., meadows) as we embark on protocol development and implementation. In addition, SIEN will investigate the newly-available Multiple Species Inventory and Monitoring (MSIM) protocol, which that has been designed to collect statistically valid information on a wide range of plant and animal species over a broad area and at a minimal cost. The MSIM is apparently a robust monitoring protocol, with repeated sampling, that obtains basic presence and distribution data for a large number of plant and animal species and condition data for their habitats.

Additional information regarding monitoring conducted by USDA Forest Service, as well as other agencies and organizations located throughout the Sierra Nevada, is described in Appendix H.

Chapter 2 CONCEPTUAL ECOSYSTEM MODELS

> *"The selection of indicators that represent the underlying ecological structure and function of an ecosystem requires the development of conceptual models of the ecological systems of interest."*
>
> —(Manley et al. 2000, Noon 2003)
>
> *"Nature is complex; models simplify. They idealize; they include what appears to be relevant and ignore the rest. They explain the world perceived by our five senses to the minds we possess in languages we have invented. They are meant to be taken seriously but not literally, they are meant to instruct and delight and make connections between diverse experiences and thereby stir the emotions."*
>
> —(Park 1988)

2.1 Conceptual Models in a Monitoring Program

A conceptual ecosystem model is a visual or narrative summary that describes the important components and interactions within an ecosystem. It uses current scientific ideas and research, as well as the knowledge obtained from years of field observations, to summarize these interactions in a simplified manner that is immediately useful for NPS managers and researchers. To a scientist, a useful model might provide a heightened insight into the workings of the phenomenon being modeled. To park superintendents, a model may be most useful when it helps bolster their confidence in the correctness of a decision that affects their stewardship of the natural resource component being modeled.

What constitutes a "good"model? Summarizing from Park (1988)--A good model must be comprehensible, plausible, intelligible, heuristic, predictive, and, moreover, contain a "measure of truth;" it is trustworthy.

What constitutes a conceptual model? Almost any explanation or diagram that describes the way something works can be a conceptual model. This includes narrative, tabular, and schematic conceptual models.

2.1.1 Narratives

Narratives are simply that – textual descriptions of the system in question. Darwin's "On The Origin of Species by Means of Natural Selection, or The Preservation of Favoured Races in the Struggle for Life" is a classic narrative model. On a more prosaic level and, certainly more appropriate to our modeling endeavors, is the observation that: "If one goes up in elevation, then one will observe a drop in the air temperature." This is a simple static model. Narrative models may use word descriptions as well as mathematical formula.

2.1.2 Tables of Relationships

Tables of relationships or "tabular models" are not uncommon in the field of conceptual modeling. A classic example is Odum's tabular model of succession (Figure 2-1) (Odum 1969). Many of the predictions of Odum's model are now known to be flawed, but as Park (1988) said, "the model must be taken seriously and not necessarily literally". At the time it was developed it aroused much interest in the field of successional ecology and a great deal of research that enriched the body of successional theory in ecology was accomplished as a result.

Ecosystem attributes	Developmental stages	Mature stages
	Community energetics	
1. Gross production/community respiration (P/R ratio)	Greater or less than 1	Approaches 1
2. Gross production/standing crop biomass (P/R ratio)	High	Low
3. Biomass supported/unit energy flow (B/E ratio)	Low	High
4. Net community production (yield)	High	Low
5. Food chains	Linear, predominantly grazing	Weblike, predominantly detritus
	Community structure	
6. Total organic matter	Small	Large
7. Inorganic nutrients	Extrabiotic	Intrabiotic
8. Species diversity variety component	Low	High
9. Species diversity equitability component	Low	High
10. Biochemical diversity	Low	High
11. Stratification and spatial heterogeneity (pattern diversity)	Poorly organized	Well-organized
	Life history	
12. Niche specialization	Broad	Narrow
13. Size of organism	Small	Large
14. Life cycles	Short, simple	Long, complex
	Nutrient cycling	
15. Mineral cycles	Open	Closed
16. Nutrient exchange rate between organisms and environment	Rapid	Slow
17. Role of detritus in nutrient regeneration	Unimportant	Important
	Selection pressure	
18. Growth form	For rapid growth ("r-selection")	For feedback control ("K-selection")
19. Production	Quantity	Quality
	Overall homeostasis	
20. Internal symbiosis	Undeveloped	Developed
21. Nutrient conservation	Poor	Good
22. Stability (resistance to external perturbations)	Poor	Good
23. Entropy	High	Low
24. Information	Low	High

Figure 2-1. Odum's tabular model of succession (Odum 1969).

2.1.3 Schematic Models

Pictures

Pictures could be ground level or aerial photographs of a landscape, or a graphic rendering. Models are produced when the pictures are interpreted and landscape elements and mosaics are superimposed upon the image. Still other conceptual models can be derived from a temporal series of photographs of the same landscape or landscape element, mosaic or component. The photographs or graphic renderings are repeated at the same place through time, and interpreted. Changes and trends revealed by the repeat photography are noted, from which, a generalized model of change can be constructed.

Box and Arrow Models (Diagrammatic Representations)

Box and arrow models, flow charts, schematic diagrams and the like are a staple of conceptual modeling. A widely used example of such a model in NPS vital signs monitoring plans is the Jenny Chapin Model as modified by Miller and Thomas (Figure 2-2) (Miller and Thomas 2004). The Jenny-Chapin model is ultimately derived from the Jenny "fundamental soil equation" (Jenny 1941) that takes the form of a mathematical proposition that establishes the multivariate relationships between soil (S), the dependent variable, and the independent variables: climate (cl), parent material (pm), relief (r), organisms or biota (o) and time(t).

$S \propto f(cl,pm,r,o,t)$.

Jenny also produced a form of the equation that implicitly accepts that other variables are also involved in soil formation. In his seminal paper, "A Functional Factorial Approach to Plant Ecology, Major (1951) extended Jenny's (1941) original concept to the formation of vegetation (V) wherein:

$V \propto f(cl,pm,r,o,t)$.

Miller and Thomas (2004) take this one step further and apply the concept to the entire ecosystem.

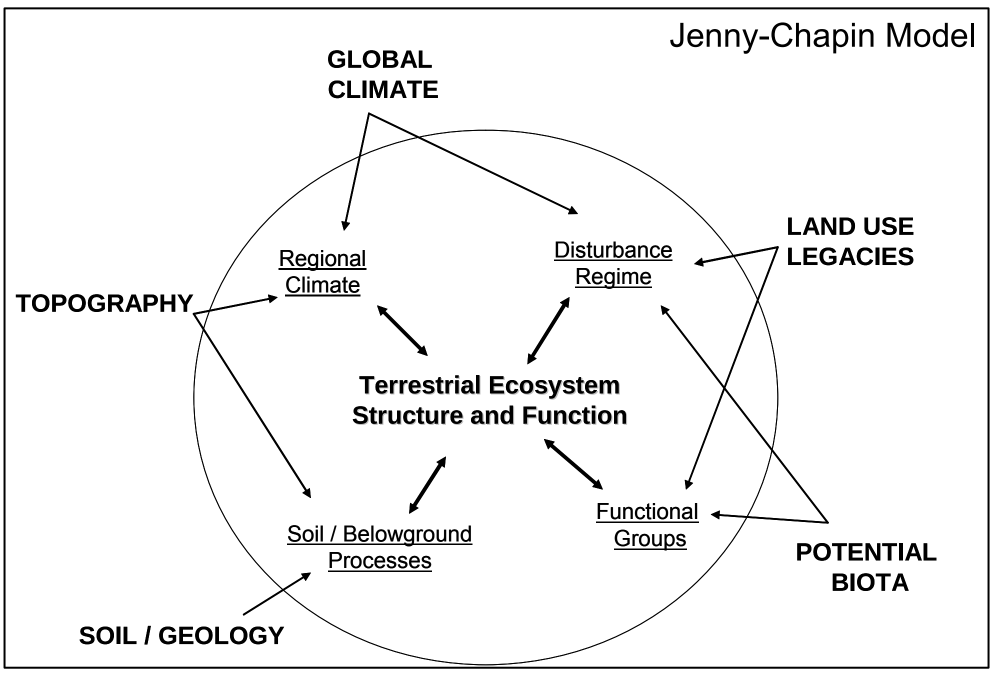


Figure 2-2. Modified version of the Jenny-Chapin model as revised by Miller and Thomas (2004). Ecosystem processes are determined by five state factors: climate, organisms, relief, parent material and time since disturbance. These factors affect control factors including functional groups, soil/water resources, atmospheric resources and disturbance at the landscape scale and interact with ecosystem processes at all scales.

Textual or propositional models described above are often interchangeable with box and arrow models as the above examples show. The form of model chosen should be the most effective way to convey the information and relationships, and model type or form should also take into account the audience for the model. The detail afforded by a table or narrative model may be more appropriate for a scientific paper, while a picture model is likely to be more effective in a presentation.

When we use conceptual models in the field of long-term ecological monitoring, it is important that they be adaptive and dynamic, as well as applicable at various spatial and temporal scales. Conceptual models, if they are good ones, help us to reduce ecosystem complexity to a manageable set of key components and processes. As we learn more about ecosystem processes, our conceptual ecosystem models that attempt to reflect those processes will change and evolve as we learn from applying the models themselves. Because of their flexibility and relative simplicity, conceptual models have the potential to play a central role throughout all phases of development and implementation of a monitoring program (Figure 2-3) (Maddox et al. 1999).

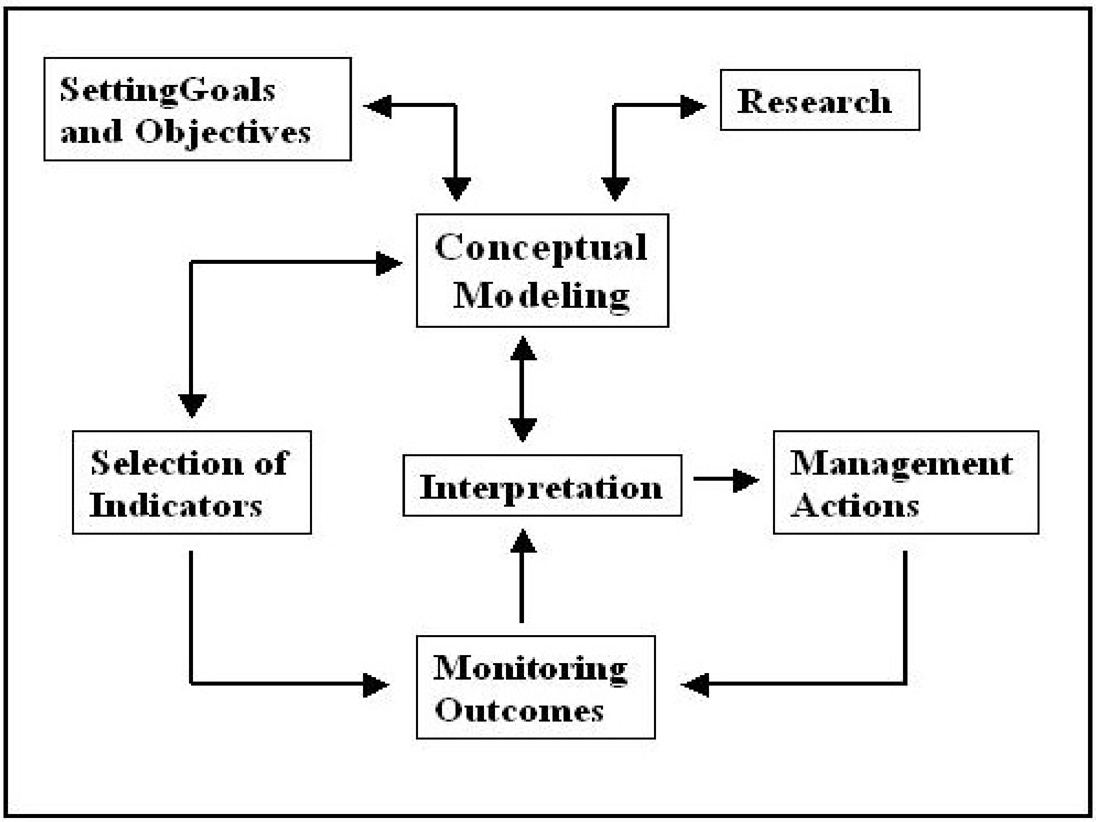


Figure 2-3. Central role of conceptual modeling in a dynamic monitoring program (adapted from Maddox et al. (1999) and Garrett et al. (2005)).

2.2 Development of Models for the Sierra Nevada Network

Development of models for the Sierra Nevada Network (SIEN) began with the Science Committee during the planning of Phases I and II of vital signs monitoring. These models helped to inform the vital signs prioritization, and subsequently, the Science Committee's selection of a subset of vital signs for protocol development. As the Network now focuses on protocol development and implementation of vital signs monitoring, conceptual models need to be more focused on the particular systems, processes, and components to be monitored.

Within our monitoring program, models have helped us to

- formalize current understanding of ecosystem structure and function as well as relationships among ecosystem components at various levels of organization (landscape, community, watershed, population)
- highlight effects of important drivers and stressors on park resources and ecosystem processes
- identify and articulate relations among ecosystem attributes of interest and indicators
- facilitate communication among participants in the iterative process of vital signs identification, prioritization, selection, and protocol development

As the Network progresses toward implementation of vital signs monitoring, the models should inform our thinking about sample design, facilitate integration and synthesis of data, and serve as communication tools about the program (Gross 2005). We hope that future models will assist us in communicating connections between management decisions and information gained from monitoring, such as identification of threshold conditions that could trigger a management action.

The SIEN sought a balance of vital signs that represented physical and biotic components of the system as well as major drivers. While we are still a long way from adequately incorporating concepts of spatial and temporal scale in our models, we do attempt to organize our models into a hierarchical framework that includes *overview, systems*, and *detailed* models (Table 2-1).

Table 2-1. Summary of conceptual models and location in document.

	Model Name	Location
Overview	General Ecosystem Model	Chapter 2, Appendix I
	Landscape Exchange	Chapter 2, Appendix I
	Stressors and Interactions	Appendix I
	Focal Systems	Chapter 2 and Appendix I
System	Atmospheric	Appendix I
	Landscape Dynamics	Appendix I
	Aquatic	Appendix I
	Meadows/Wetlands	Appendix I
	Forest	Appendix I
Detailed	Nitrogen Deposition	Appendix I
	Fire Regimes	Appendix I
	Plant Community Invasibility	Appendix I
	Hydrology	Appendix I
	Aquatic Biota	Appendix I
	Lakes	To be developed –FY2007
	Streams and Rivers	To be developed – FY2007
	Mountain Yellow-legged Frog	Appendix I
	Meadow Invertebrates	Appendix I
	Bird Populations	Appendix I

2.3 Overview Models

We present three overview models here to 1) highlight the ecosystem factors that interact with processes to structure the physical environment and its biotic communities; 2) illustrate inputs and outputs (or exchanges of materials and organisms) that affect the Sierra Nevada landscapes: and 3) highlight the focal systems and processes we target for monitoring.

2.3.1 General Ecosystem Model

The environment in the Sierra Nevada is a function of the interactions among the physical factors of topography, geology, regional climate, and the available organisms (Figure 2-4). These factors are inextricably linked to the abiotic and biotic ecosystem components including local climate, hydrology, soils, vegetation, and wildlife. The distribution and abundance of the biotic communities in the network parks are directly influenced by these interactions.

Implicit in Figure 2-4 (in the arrows) are the processes that shape the physical environment and influence the distribution and abundance of organisms. The processes include processes of weathering, mineralization, erosion, and decomposition that affect soil and water quality; climate-driven processes of change that include fire, flooding, avalanches, and hillslope sediment transport; and biotic processes such as reproduction, growth, mortality, predation, herbivory, and pollination.

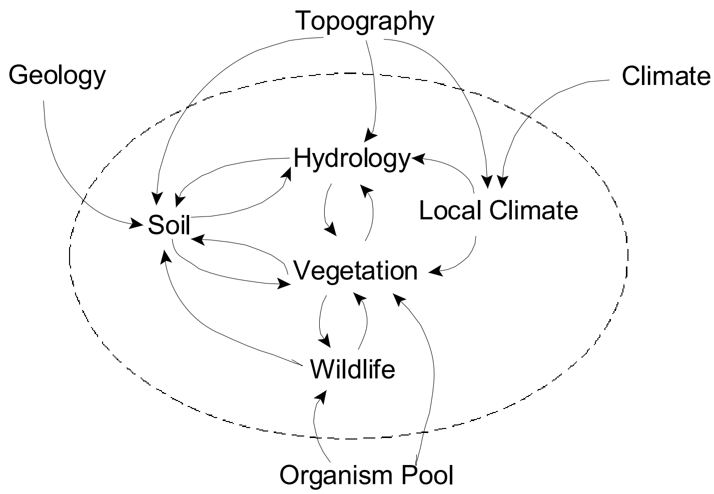


Figure 2-4. General ecosystem model for Sierra Nevada. Topography, climate, geology, and organisms interact with each other and ecosystem processes to determine habitat quality and the resulting biotic community distribution, structure, composition, and function. Model courtesy of J. van Wagtendonk, USGS-Western Ecological Research Station, Yosemite National Park.

2.3.2 Landscape Exchange

A landscape can be thought of as an "open" system that can exchange energy, materials, and organisms with its surroundings. In this context, broad-scale processes *constrain* these exchanges among landscapes. For example, the regional climate could be considered a constraint on the Sierra Nevada landscape. Park "boundaries" are mostly arbitrary delimitations with respect to atmospheric, hydrologic, and other ecosystem processes.

The extent (area) of a landscape influences the "openness" of a landscape. For example, in the Sierra Nevada Network—does Devils Postpile National Monument have special needs or problems because it is a smaller unit? Will a non-native species or a natural disturbance disproportionately affect the monument? Landscapes of small extent may be more profoundly influenced by their surroundings than those of larger extents, which may be able to compensate for disturbances in one area within the park.

The major interactions between a Sierra Nevada landscape or park and the surrounding landscape are illustrated in Figure 2-5. Many of these exchanges are common to all Sierra Nevada landscapes regardless of shape, size, or locality. Some external inputs are little influenced by the parks themselves. These include meteorological inputs (e.g., precipitation, solar radiation) and airborne pollutants (e.g., nitrogen, persistent organic pollutants). The Sierra Nevada landscape exchanges energy, materials, organisms, and processes with the larger landscape within which it is embedded. For example, birds and other animals freely cross the boundary between park and non-park habitats. Fire can propagate into or out of a park unit. Non-native invasive species that are present outside the boundaries can be transported into a park area by wind, animals, or human activities. River flows can originate from a park and cross the boundary to lower elevations, or may only flow through a park and therefore not encompass the uppermost reach of the watershed (e.g., San Joaquin River through Devils Postpile). Implications of these exchanges (of materials, organisms, etc.) for park resources need to be explored and related to management concerns. Although we can't control what comes in, we can monitor effects, communicate the information widely, and mitigate the effects to some extent through thoughtful management.

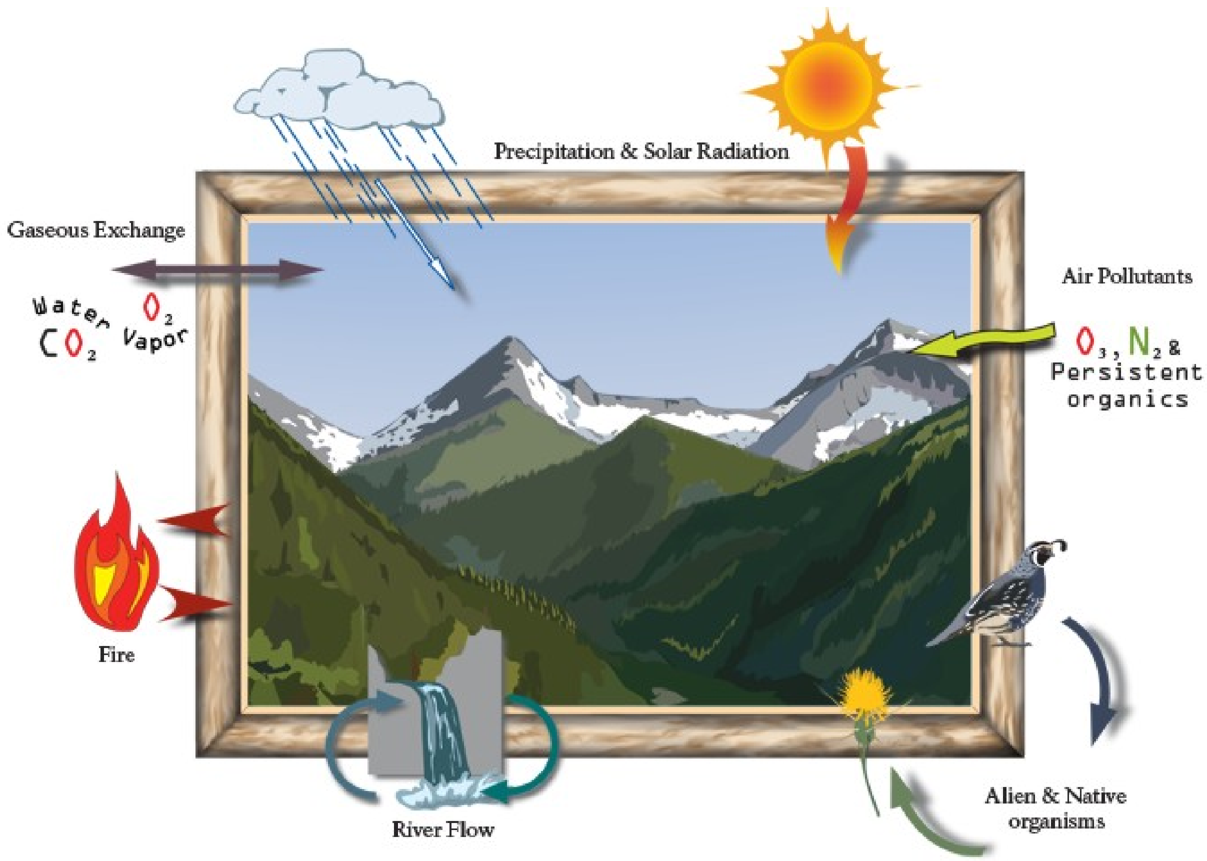


Figure 2-5. Major inputs and exchange of energy, materials, organisms, and processes for a given Sierra Nevada landscape and its physical surroundings. Illustration by Justin Hofman.

2.3.3 Sierra Nevada Network Focal Systems

There are limitations to monitoring at the temporal and spatial scale of landscape mosaics and processes, and a balanced monitoring program includes finer resolution snapshots of the ecosystem that focus in on specific systems, communities, populations of organisms and physical attributes. While we want to represent many biotic and physical aspects of the ecosystem in a monitoring program, the size and complexity of the Sierra Nevada Network landscape requires that we focus our monitoring efforts on a few focal systems and drivers. Through Network workshops, Science Committee meetings and Board of Directors review (described in Chapter 3), we identified components of aquatic, coniferous forest, and meadow/wetland systems as a focus for long-term monitoring due to the ecological significance, sensitivity to major drivers (and anthropogenic stressors), and management priority of these particular systems.

The interrelationships among these systems as well as the major divers that influence them are shown in Figure 2-6.

2.3.3.1 Major Drivers

This section discusses the major drivers that influence Sierra Nevada landscape dynamics and the focal systems selected for monitoring.

Atmospheric System

The atmospheric system drives weather, and at longer time scales, climate. Climate strongly influences the landscape by determining the flux of both energy (solar radiation) and mass in the form of moisture (rain, snow, water vapor). Stine (1996) generalizes that climate exerts a predominant influence on the components of the Sierra Nevada landscape:

- Vegetation (type, biomass, distribution)
- Hydrology (size, distribution, fluctuations, and water quality of lakes and streams)
- Soils (thickness, stability, nutrient capacity)
- Landforms (rates of formation and loss)
- Fire (location, frequency, seasonal timing, intensity and/or severity)

Climate varies spatially and at annual, decadal, centennial and millennial time scales. Numerous paleoecological studies have documented vegetation changes over the past many thousands of years in response to changes in climate. Woolfenden (1996) summarizes that during the Quaternary period of the past 2.4 million years, at least six successive major glacial cycles covered the Sierra Nevada with ice caps and mountain glaciers, filled lake basins in the adjacent deserts, and lowered the elevation limits of plant species. These ice ages were interspersed with shorter warm intervals when habitats expanded into northerly latitudes and tree lines gained elevation. Species responded individualistically to these changes, sometimes assembling into communities with no modern analog (Woolfenden 1996).

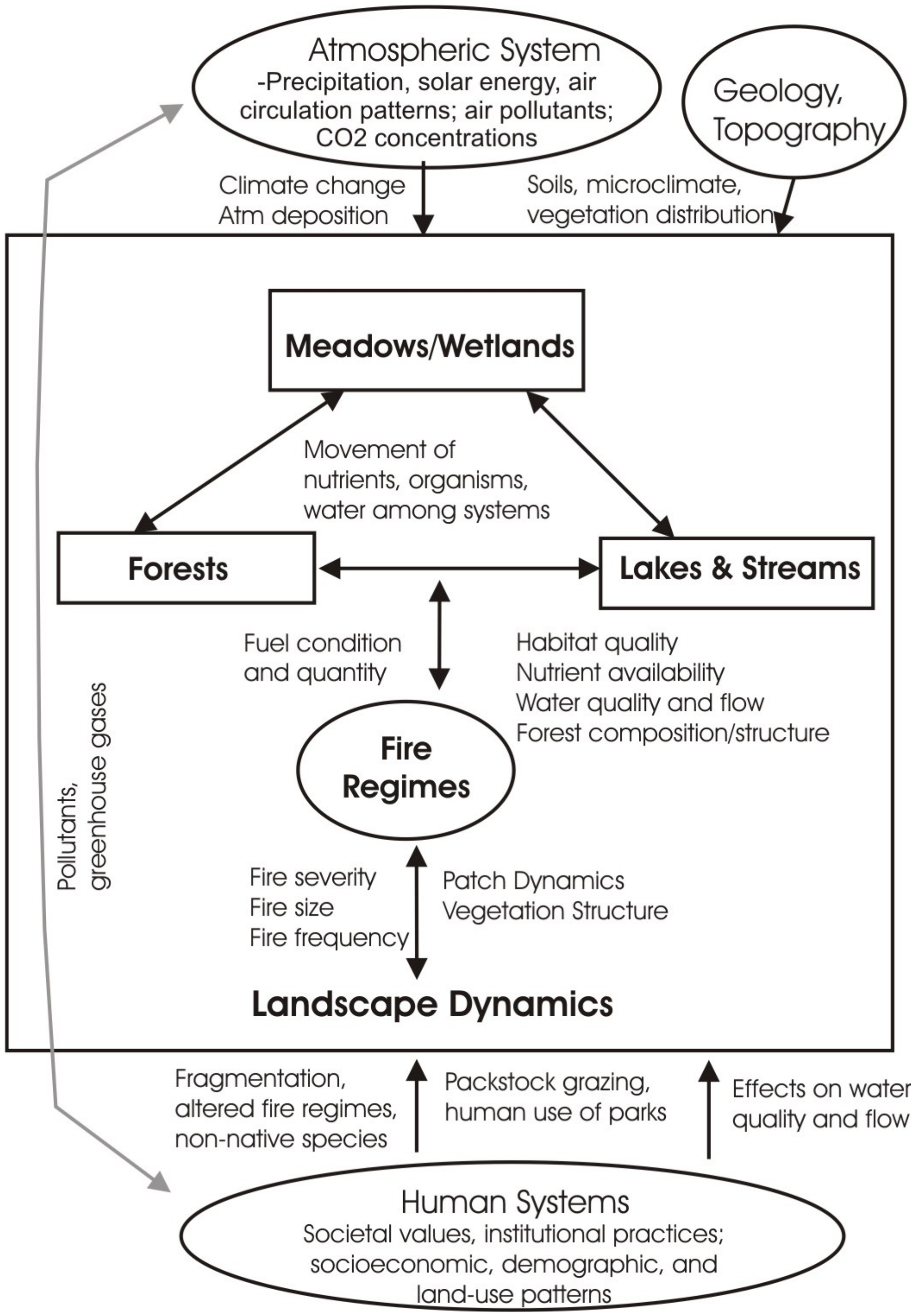


Figure 2-6. Landscape dynamics, along with aquatic, forest and meadow/wetlands systems are the main focal systems for SIEN vital signs monitoring. Major drivers are shown in ovals and include anthropogenic influences on the Sierra Nevada; major drivers are also a focus for vital signs monitoring, especially climate, fire, invasive plants and air pollutants.

Climate affects the distribution of forest types and other plant communities of the Sierra Nevada through its influence on the soil water balance Stephenson (1988, 1998). With increasing elevation, temperature decreases (causing decreasing evaporative demand) while precipitation increases. The mixed-conifer zone of the Sierra Nevada is sandwiched between low-elevation sites that are chronically droughty, and high-elevation sites that are too cold to be very productive (Urban et al. 2000). Thus, these systems are quite sensitive to climate variability (Graumlich 1993, Swetnam 1993). The soil moisture regime interacts strongly with forest productivity (via fuel loads) and climate (via fuel moisture), and thus these systems are especially responsive to the fire regime as it interacts with forest dynamics and climate (Miller and Urban 1999c, Miller and Urban 1999a, b).

The predicted potential effects of anthropogenic climate change on the Sierra Nevada were discussed in Chapter 1. These effects will likely be highly synergistic, affecting a host of physical and biological systems in unpredictable ways (CIRMOUNT Committee 2006). Climate change will likely exacerbate other system stressors, especially altered fire regime, air pollution, and non-native invasive plants, in addition to the estimated effects it may have on the hydrologic system and plant and animal life cycles and distributions.

In addition to influencing weather and climate patterns, atmosphere dynamics interact with topography to influence air patterns, affecting the distribution and deposition of pollutants. Ozone, agricultural pesticides, particulate matter, and nitrogen compounds are a few examples of pollutants deposited through dry and wet deposition in Network parks (see Chapter 1 and Appendix C for more detail on pollutants, sources, and air flow patterns).

Fire in giant sequoia-mixed conifer forest. NPS photo.

Fire

The importance of fire as a key process and driver in the Sierra Nevada was discussed in Chapter 1. Here we emphasize the linkages between fire and climate and their roles in influencing vegetation pattern and various ecosystem processes. Climate primarily affects fire regime through its direct effect on fuel moisture. A short period of dry, hot weather can severely dry fuels, often overwhelming any effects that might be due to fuel loads or fuel bed structure. Climate also affects the geographic distribution of vegetation types and site productivity, and, thus, indirectly influences the intensity, frequency, and size of fires (Miller and Urban 1999c). Fire frequency tends to decrease with increasing elevation and soil moisture (Figure 2-7), interacting with topographic moisture gradients and fuel availability to help shape vegetation distribution and landscape pattern. Over longer time scales, climatic fluctuations are responsible for variations in fire regimes (Clark 1988, Swetnam 1993).

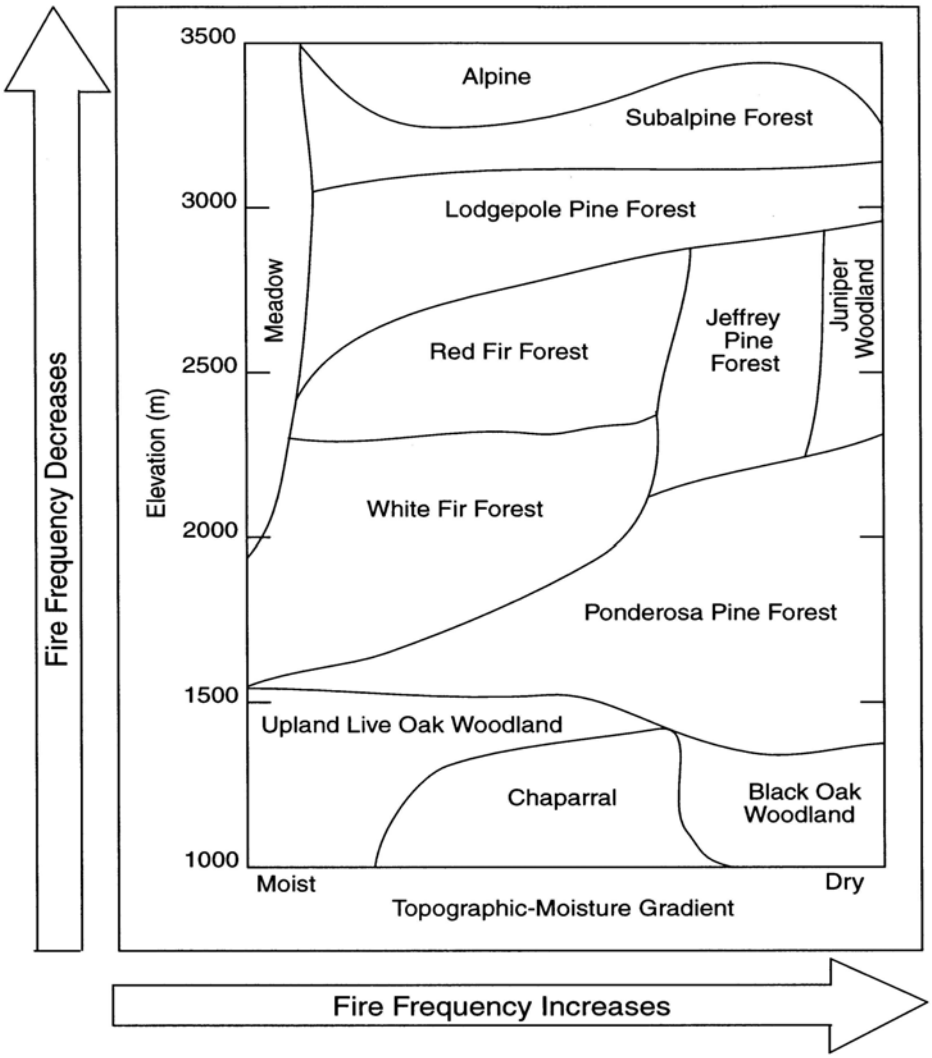


Figure 2-7. The distribution of general vegetation types (Vankat 1982) and the relation of fire frequency to elevation and topographic gradients in Sequoia National Park (Miller and Urban 1999c). This figure does not distinguish the differing effects of evaporative demand vs. water supply on vegetation distribution. See Figure 2-8 for an updated approach to modeling forest distribution based on topographic and water balance factors.

We can also consider fire a process that helps link terrestrial vegetation with aquatic, atmospheric, and soil systems. Several Sierra Nevada studies have documented increases in stream solute concentrations after fire (Chorover et al. 1994, Williams and Melack 1997a, b, Heard 2005), probably due to increased runoff, changes in biogeochemical processes, and direct deposition of ash into waterbodies. Burning and decomposition of plant material, accelerated mineralization and erosion rates, and decreased nutrient uptake by vegetation also lead to increases in solute concentrations in soil solution (Raison 1979, DeBano et al. 1998). While many elements, particularly Nitrogen, Sulfur, and Carbon are converted to volatile compounds and lost to the atmosphere (Covington and Sackett 1984, Caldwell et al. 2002), high concentrations of these elements are also left behind in ash layers and partially combusted organic material (Blank and Zamudio 1998). Fire may accelerate some losses of nutrients through combustion and leaching, but it also plays a critical role in supplying available nutrients to terrestrial and aquatic systems (St. John and Rundel 1976, Romme and Knight 1982, Hauer and Spencer 1998). Fire releases nutrients bound in above-ground organic matter and makes them available in organic forms for plant and microbial uptake.

In summary, fire is a process that helps link terrestrial, atmospheric, and aquatic systems through its role in moving nutrients across these systems. Fire regimes in combination with climate and topography, shape vegetation structure and pattern on the landscape, affect water quality and quantity, and indirectly affect wildlife habitat.

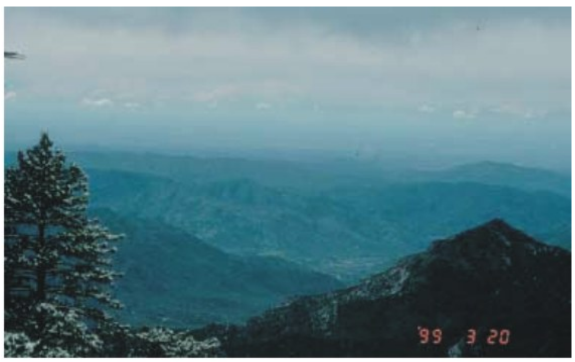
Geology and Topography

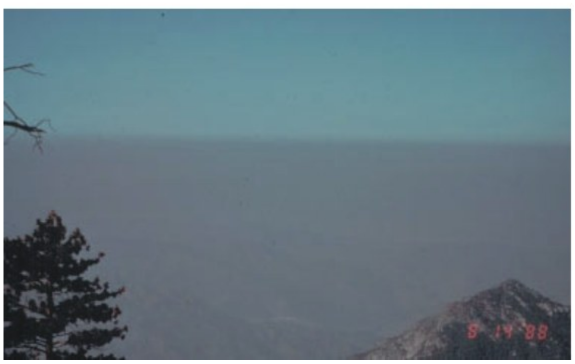
Glacially-carved Tehipite Valley in Kings Canyon National Park. NPS photo.

The Sierra Nevada physical landscape was shaped by glaciation, volcanism, erosion, and deposition. The varied topography provides habitat diversity for plant and animal communities. As described in Chapter 1, the elevation gradient influences local weather and climate patterns, with a general trend of temperatures decreasing and precipitation increasing with elevation. Because the mountains create a rain shadow, significantly less moisture falls throughout the season east of the Sierra Nevada crest. Topography also influences microclimatic conditions through variations in aspect, e.g., north aspects have lower temperatures and thus evaporative potential. So they tend to be more moist and cooler than south-facing slopes. Soils vary in type and depth, influencing plant community distribution through their nutrient availability and water-holding capacity. See Figure 2-8for the influence of aspect and soil depth on forest distribution.

Human Systems

California has 34 million people, by far the most populous state in the Union. The San Joaquin portion of California's Central Valley, located to the west of the Sierra Nevada Network parks, is a region that holds a population of 3.4 million or ten percent of California's population, according to the 2000 census (United States Census Bureau 2003). By the year 2020, the San Joaquin portion of the Central Valley will have over six million people according to population projections by the California Department of Finance (Report 93 P-1). The Sierra Nevada parks are also within four to five hours of driving distance from the largest cities of California.





A view from Sequoia National Park toward California's Central Valley, contrasting a good air quality with a bad air quality day. NPS photo.

Current regional levels of population, agribusiness, and other industry combine with topography and weather patterns to result in some of the worst air quality in the country (see Chapter 1 and Appendix C). In addition, California agriculture uses a large percentage of water resources in the state. If state and regional population numbers double between 2000 and 2020, this will inevitably change land use patterns and have a dramatic influence on quantity of arable land, air quality, water quality and availability, energy resources, and biodiversity. These changes will have direct effects on park resources in the form of atmospheric transport and deposition of pollutants and nutrients, light in night skies, noise from overflights, increased development and urbanization, increased park visitation, and more greenhouse gas emissions accelerating global climate change.

Societal values and social systems govern many of the interactions of the human system with the Sierra Nevada eco-region and parks. For example, the popular press increasingly cites evidence of a weakening of the historically strong link between Americans and the natural world. Writers cite many different forms of evidence for this trend, including stagnant visitation statistics for national parks and continued declines in the number of Americans who sport hunt (Tweed 2006). Sustaining support for wildlands preservation in a democracy, it has long been believed, depends upon substantial numbers of citizens using and enjoying their public lands. In addition to the effects of public policy and federal laws that modify human interactions with the landscape, personal values also affect the long-term compatibility of land use and wildlands resources preservation. Future changes in socioeconomic, demographic, and land-use patterns in combination with changes in social systems and values will present many challenges for Sierra Nevada Network parks.

2.3.3.2 Focal Systems--Description

Meadows/Wetlands

Meadows concentrate resources, provide critical habitat for both resident and transient animals, and have been identified as key ecosystem elements in the Sierra Nevada Network parks. Meadows are diverse and complex ecosystems that vary widely in character and composition, although occupying only a small fraction of the land surface of the Sierra Nevada (Benedict and Major 1982, Ratliff 1982). Meadows form in catchments where soils are saturated or flooded for at least a part of the year. Sierra Nevada meadows range in size from small patches to large expanses, such as Tuolumne Meadow in Yosemite National Park. Most Sierra Nevada meadows occur above snowline, where snowmelt provides moisture during the summer growing season. In addition to surface flow, moisture enters meadows from streams and from sub-surface flows that are forced to the surface by local geomorphology. Meadows can be characterized as wet, moist or dry, reflecting the relative availability of moisture during the summer growing season. Sierra Nevada meadow vegetation is dominated by perennial graminoids, which reflect the relatively short growing season of the middle and high elevations.

Sampling invertebrates in Tuolumne Meadow, Yosemite National Park. Photo by Jutta Schmidt-Gengenbach.

As wetlands, wet meadows provide important ecological and cultural functions. Some of the functions described by Mitsch and Gosselink (1993) and Williams (1990) that might apply of the Sierra Network meadows include: 1) influencing regional water-flow regimes including flood mitigation by intercepting and slowing the release of water to streams; 2) improving water quality by removing nutrients and toxic materials; 3) sediment trapping; 4) sources for some of the highest productivity in the world; 5) important habitat for wildlife; and 6) aesthetic values to the people that visit them. Peat-accumulating wetlands in their natural condition remove and store carbon. If altered, such as by drainage, the process would reverse contributing to atmospheric carbon dioxide through oxidation (Gorham 1991). Wetlands play an important role in the nitrogen and sulfur cycles. A more complete description of meadow and wetland systems can be found associated with the meadow conceptual model in Appendix I.

Aquatic Systems: Lakes and Streams

As summarized in Chapter 1, the Sierra Nevada parks span seven major watersheds and contain a diversity of water resources, including over 4,500 lakes and ponds, thousands of kilometers of rivers and streams, seeps, wet meadows, waterfalls, hot springs, mineral springs and karst springs. Water is a vital resource in the Sierra Nevada, both ecologically in the parks, and economically in the broader region. We are interested in monitoring water resources both for their sensitivity to important drivers and stressors (climate, fire, air pollution, invasive species) and their link to other critical biotic and physical resources.

Alpine lakes in Evolution Basin, Kings Canyon National Park. NPS photo.

Through the hydrologic cycle (See Appendix I – hydrologic model), water is linked to the atmospheric and terrestrial systems. In the Sierra Nevada, the snowpack that accumulates in the winter serves as a reservoir for water that is released gradually in the spring to the aquatic system of groundwater, wetlands, streams and lakes to be available during the dry summer growing season. Both the quantity and quality of water help to determine the condition of terrestrial as well as aquatic biological systems.

High elevation lakes and streams in the Sierra Nevada are oligotrophic, have a low buffering capacity, and are sensitive to change from atmospheric deposition of nutrients, toxic substances, and acids (Goldman et al. 1993, Leydecker et al. 1999, Davidson and Shaffer 2002, Sickman et al. 2003). Change detected in high-elevation lakes can be an early warning indication of change that may eventually occur at other elevations and ecosystem types. To complement the early warning indicators at high elevation aquatic systems, monitoring of water quantity and quality in mid- to low-elevation streams and rivers can indicate cumulative effects of changing terrestrial and aquatic ecosystem processes and disturbances that take place throughout a watershed.

Water availability is a major driver in the distribution of plant communities. Thus, tracking water quantity changes over time may provide an early warning of later changes in soil moisture that could cause gradual shifts in plant population dynamics and community distributions on the landscape.

Forests

Sierra Nevada montane and subalpine coniferous forests comprise one of the largest and most economically important vegetation regions in California (Rundel et al. 1988). They are very complex in composition, structure, and function (Franklin and Fites-Kaufmann 1996). We are interested in monitoring forest dynamics, and primarily—birth, growth and death rates of trees, because they are sensitive to changes in the two major drivers in the Sierra Nevada: climate and fire regimes. These two drivers are subject to substantial alteration by human impacts, and in these altered states can act as stressors on forest systems.

Giant sequoia-mixed conifer forest. NPS photo.

Sierra Nevada forest distributions are linked to moisture availability as determined by topography, soil depth, and evaporative demand (Figure 2-8). Moisture availability affects growth, recruitment and death rates of trees as well as frequency and intensity of fire.

Recent research results suggest that forest dynamics may already be showing effects of climatic changes. Forest turnover rates (defined as the average of tree mortality and recruitment rates) have been increasing in tropical Amazonia (Phillips et al. 2004) and in the Sierra Nevada (Stephenson and van Mantgem 2005). In the Sierra Nevada, a possible cause for this more rapid forest turnover rate is that summers have been getting warmer and drier. Snowpack has been decreasing over most of the West in recent decades (Mote et al. 2005) and spring streamflow has been occurring earlier (Stewart et al. 2004).

Sierra Nevada montane forests are highly dependent on fire (See Chapter 1 and Appendix I for more detail). A variety of studies suggest that past Sierran mixed conifer forests had lower tree density, and very different demographic distribution of age classes—with lower fuel loads and greater landscape diversity of forest patches than current forests (Vankat and Major 1978, Parsons and DeBenedetti 1979, Bonnicksen and Stone 1982, Vale 1987, Ansley and Battles 1998, Roy and Vankat 1999, Stephenson 1999). While many of the changes observed in forest structure and function are thought to be primarily due to fire exclusion, they may also be related to warmer, moister conditions of the 20th century (Graumlich 1993, Scuderi 1993, Keeley and Stephenson 2000).

Monitoring of forest dynamics will need to be linked to monitoring of fire regime, fire effects, and climate to enable effective interpretation of trends in tree population dynamics and large-scale forest landscape changes in pattern and structure.

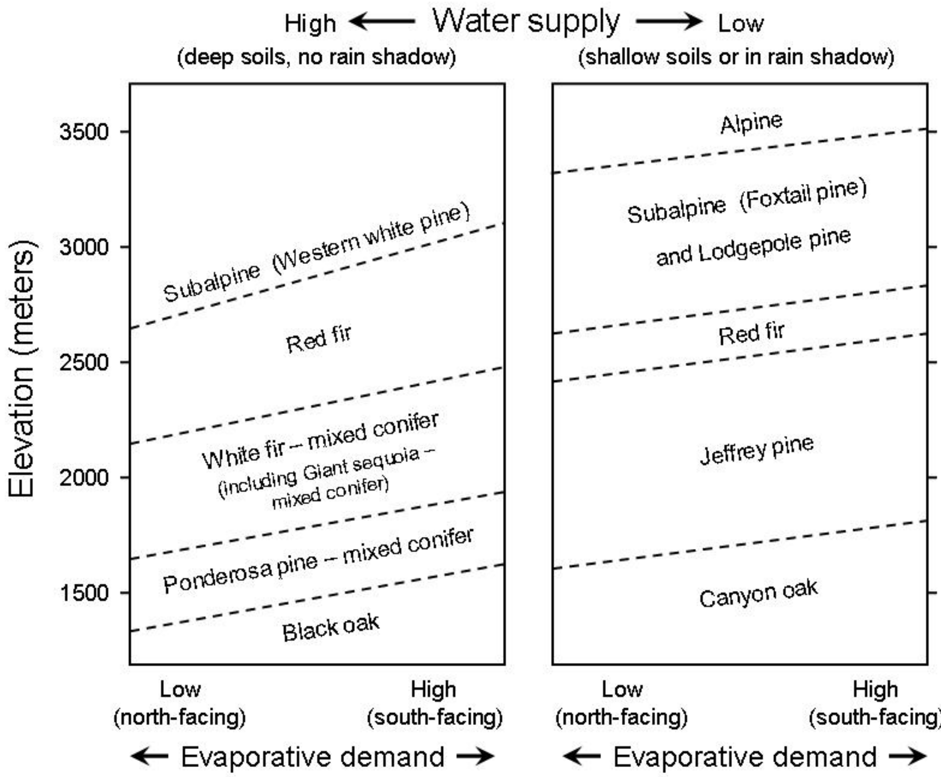


Figure 2-8. The approximate distribution of forest types in the southern Sierra Nevada relative to elevation, evaporative demand, and water supply. Only upland forest types (away from open water and meadow edges) are shown. Forest types intergrade extensively, so that boundaries between types are not sharply defined. In particular, intergradation between foxtail pines and lodgepole pines is so extensive that no boundary between the two types is shown, although foxtail pines dominate at the highest elevations, lodgepole pines at lower elevations. Because deep soils able to retain abundant water disappear at high elevations, no upper treeline is indicated in the high water supply diagram. Modified from Stephenson (1988).

2.4 Future Development and Applications of Models

The Sierra Nevada Network will need to further develop conceptual models for the following purposes as protocols are developed and implemented, monitoring results need to be analyzed and interpreted, and the information must be shared with a variety of audiences.

- Outreach/communication: Attractive, simple pictorial models that explain focal systems and relationships of components and drivers for interpretive applications, general audiences, and perhaps, web pages.
- Information Interpretion/Gap Identification: complete models that elaborate more detailed relationships among components and drivers, capture improved understanding from on-going research and monitoring projects, and identify specific gaps in understanding in various systems.
- Prediction: Predictive models that use actual data to identify areas most sensitive to climatic change, most vulnerable to non-native plant invasions, or most affected by nitrogen deposition and ozone pollution.
- Simulation and analysis: Mathematical, statistical, or null models that predict patterns of species diversity, niche overlap, and species co-occurrence. Some networks in the NPS are beginning to use modeling simulation programs such as EcoSim (Gotelli and Entsminger 2006).

The Network will need to consider modeling capability in its development of university partnerships and long-term network staffing, as conceptual and predictive modeling will be an integral part of monitoring program development, data analysis and interpretation, and communication and outreach.

Chapter 3 IDENTIFYING AND PRIORITIZING VITAL SIGNS

Identifying and selecting *vital signs* for the SIEN Inventory and Monitoring Program has required years of research and teamwork. Since 1999, scientists, administrators, and many others throughout the Sierra Nevada Network have been working together to select and prioritize vital signs. The current list of 33 candidate vital signs represents a balance of ecosystem driving variables (e.g., weather, climate) and response variables—communities and species (Bennett et al. 2003).

3.1 Summary of Vital Sign Prioritization Process

The vital signs selected provide a focus for monitoring at different spatial and temporal scales. They represent a mix of sensitive and early indicators, as well as slower responding, more integrative indicators. Although we realize it will not be possible to monitor all of these vital signs in the immediate future, they do represent a powerful and balanced guide for developing an integrated long term monitoring program.

Network staff and partners developed and refined this list through a process that included meetings, workshops, and ranking exercises to produce a shortened list of candidate vital signs for the Network to use for feasibility analyses. From this list, SIEN's science committee (comprised of I&M, park, and partner staff) chose twelve vital signs to develop and implement monitoring protocols for during the next two to three years (i.e., Phase III).

In this chapter, we describe how we identified and prioritized potential vital signs, and subsequently, selected a reduced "working" list of candidate vital signs for the Sierra Nevada Network. We also describe in more detail the twelve vital signs we will focus on during the next two years for protocol development and implementation. These descriptions include *definition*, *justification*, and *preliminary monitoring* objectives.

3.2 Selecting Vital Signs

Selecting and prioritizing vital signs has been a multifaceted process of park-level workshops, targeted scoping workshops, Science Committee meetings, literature review, and conceptual model development. Over the past two years (thanks to program funding and hiring of the first permanent I&M staff), the Network has been able to further identify and refine Network-relevant vital signs. Development and refinement of the vital signs list was conducted in concert with development and refinement of conceptual models (see Chapter 2).

3.2.1 Preliminary Identification of Vital Signs

When Network-wide vital signs prioritization began, a list of 86 potential vital signs had been synthesized (development of this list is described below). Throughout the Network prioritization processes (Figure 3-1 and Table 3-1), each of the 86 Network vital signs was evaluated in context of relevance

- Is the vital sign relevant to National Park Service monitoring goals?
- Is the vital sign relevant to Network monitoring objectives?
- Is the vital sign relevant to Network resources management?

- Is the vital sign responsive to known Network anthropogenic stressors?
- Does the vital sign provide information about Network key ecosystems, communities, or processes?
- Is the vital sign important in context of the conceptual models of the Sierra Nevada?

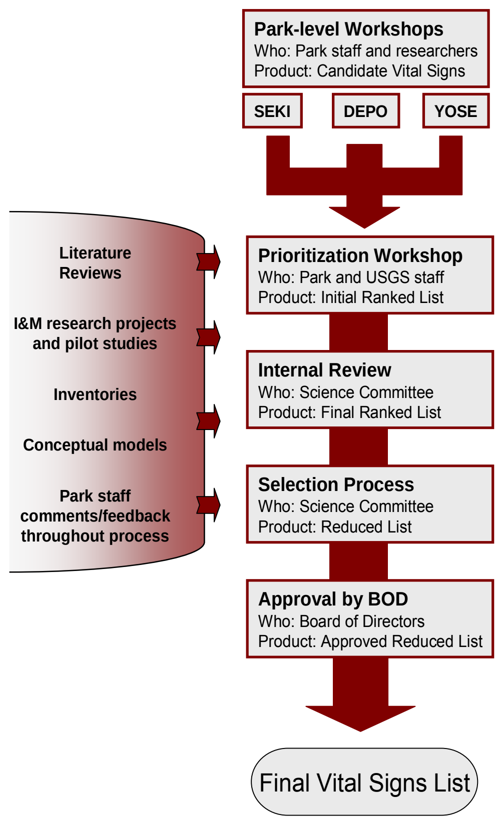


Figure 3-1. Vital signs identification, prioritization and selection process for the Sierra Nevada Network.

Park-level workshops—comprised of staff from NPS, USGS-WERC, and outside researchers and subject-matter experts—generated the initial list(s) of Network vital signs. For several years, these workshops took place without the assistance of vital signs monitoring funds or a paid permanent staff dedicated to the project.

The Science Committee generated a Network-wide, broad and comprehensive list of 86 vital signs (see Appendix J) by refining the three individual park-based lists (i.e., combining similar vital signs, adding vital signs (e.g., air and water resources which are already being monitored within parks), reviewing the literature, and developing and refining conceptual models. The Science Committee gave special attention to the five major anthropogenic stressors of the ecology of the Sierra Nevada: rapid anthropogenic climate change; altered fire regimes; non-native invasive species; air pollution; and habitat fragmentation and human use.

Table 3-1. Timetable of meetings and workshops employed by Sierra Nevada Network staff to generate and prioritize vital signs.

Date	Event	Purpose	Product
April 1999	Park-level vital signs workshop (Sequoia & Kings Canyon)	Generate list of potential vital signs, via brainstorming, by subject-matter groups	Summary Report
April 2002	Park-level vital signs workshop (Devils Postpile)	Generate list of potential vital signs, via brainstorming, by subject-matter groups	Summary Report
April 2002	Park-level vital signs workshop (Yosemite)	Generate list of potential vital signs, via brainstorming, by subject-matter groups	Summary Report
January–December 2004	Interdisciplinary Committee: I&M staff and Science Committee synthesize Network list of Vital Signs	Synthesize network-level VS lists (using individual park-level lists). Network list comprises 86 candidate vital signs.	Appendix J
January–October 2004	Science committee meetings with Sierra Sciences, Ltd.	Conceptual Model Development	Phase I Plan
March 2004	Network Vital Signs Prioritization Workshop attended by park resource, USGS, and I&M staff.	Rank list of 86 vital signs in four broad categories: physical, wildlife, vegetation, ecosystem process/human-use	Appendix J
April 2004	Science committee meetings and use of revised conceptual models, literature	Reduce candidate VS list	Table 3-3
November 2004–September 2005	Science committee and results of VS prioritization workshop, peer review, and WASO guidance	Conceptual Model development and revision, continued.	Phase II Plan
Spring 2006	Formation of Network-level vital signs workgroups (discussed in Chapter 5)	Refine vital signs monitoring objectives, determine workgroup method for proceeding with completion of Monitoring Protocols,	Protocol Development Summaries (FY2006) Monitoring

Date	Event	Purpose	Product
		protocol and literature review; work groups are composed of SIEN, SEKI, YOSE and USGS-BRD staff.	Protocol(s) (FY2007-2010)
January–December 2006	Workgroup meetings; Science committee meetings	Examine opportunities for integration of vital signs (see Chapter 5)	Integration of vital signs (e.g. Meadow Ecological Integrity Protocol, Lake Protocol)
January–December 2006	SIEN staff (and SEKI–Pat Lineback)	Refine Chapters 1-3; Write Chapters 4, 5, 6, 7, 8, 9, and 10; refine Appendices	Phase III Plan

3.2.2 Prioritization

The next stage of the vital signs process was a Network-wide vital signs prioritization workshop held in March 2005. In two days, approximately 40 participants, divided into four subject-area workgroups (physical, wildlife, vegetation, and ecosystem process/human-use) ranked relevant subsets of vital signs generated from the broad, comprehensive list.

Detailed supporting information (*justification*) for each vital sign was provided, including a full description of the vital sign in context of the Network, stressors, and management issues. Potential monitoring questions, measures, and partnership opportunities (e.g., working with other agencies) were noted where appropriate. This information was entered into a Microsoft Access database, adapted from the Mojave Network. The database allowed groups to enter prioritization scores at the workshop based on a set of criteria (Table 3-2) compiled from the NPS Inventory and Monitoring Program (http://science.nature.nps.gov/im/monitor/docs/CriteriaExamples.doc). At the conclusion of the workshop, vital signs ranks could quickly be calculated in the database, enabling the group to view the resultant ranks and discuss them immediately. The ranked list of 86 vital signs is included in Appendix J.

Table 3-2. Criteria applied to each of the 86 candidate vital signs, including weighting applied to each criteria category for ranking purposes.

Category (weight)	Criteria if *strongly* agree (score=1), otherwise (score=0)
Ecological Relevance, Geographical Scope, Data Response & Sensitivity (60%)	• There is a strong, defensible linkage between the vital sign and the ecological function or critical resource it is intended to represent.
	• The vital sign represents a resource or function of high ecological importance based on the conceptual models of the system and the supporting ecological literature.
	• The vital sign has broad geographic scope—it occurs in at least two out of three network units (Devils Postpile, Sequoia & Kings Canyon, and Yosemite) and has broad spatial extent within the parks or across the region.
	• The vital sign is anticipatory. It can signify an impending change in the ecological system or in important resources.
	• The vital sign is sufficiently sensitive to small changes in linked or related resources or functions.
	• Baseline data exist within the region and/or threshold values are specified in the literature that can be used to measure deviance from a desired condition.
Management Relevance & Utility (40%)	• There is an obvious, direct application of the data to key current or future management decisions.
	• Monitoring results are likely to provide early warning of resource impairment, and will thereby save park resources and money.
	• Data are of high interest to the public.
	• There is a direct application of the data to performance (GPRA) goals and long-term planning.
	• The vital sign is an extremely vulnerable or at-risk resource or process.

Using the ranked results of the prioritization workshop, as well as comments and recommendations from workshop participants, the Science Committee reevaluated each vital sign and categorized them based on scientific merit and context. Vital signs that are already part of established ongoing monitoring programs were also included and categorized on merit, etc., as well.

Finalization of the candidate vital signs list occurred through several subsequent meetings of the Science Committee. Vital signs were categorized as follows:

1. Tier 1: Vital signs considered to be good indicators of the larger ecosystem or resource condition (some of these are included in Table 3-3). Detailed descriptions of vital signs chosen for protocol development during the next two years can be found in Appendix K (Protocol Development Summaries). Also, see Appendix J.

2. Tier 2: Vital signs that we consider to be good indicators of the larger ecosystem, but for which protocol development will not proceed until on-going research indicates monitoring will be feasible or until additional funds are identified.
3. Vital signs not considered to be good indicators of the larger ecosystem (at least with information currently available), but are themselves a resource important to monitor (e.g., dark night sky, soundscape) (Table 3-3 and also Appendix J).
4. De-listed Vital Signs—those identified as a weak vital sign, or a vital sign whose condition could be improved by straightforward management action (e.g., stock use) (see Appendix J).

Detailed descriptions of vital signs in categories 1 and 2 (Tier 1 and Tier 2) can be found in Protocol Development Summaries (Appendix K).

Table 3-3. Reduced "working" list of vital signs generated by Network-wide prioritization (workshop and Science Committee) and relevance to each park unit. Vital signs selected for protocol development in the next two years are bolded (and described in detail in Appendix K—Protocol Development Summaries). Other vital signs that the Network hopes to pursue soon, if on-going research indicates methodology will be feasible are italicized. See key below the table for symbol explanation.

Level 1	Level 2	Vital Sign	DEPO	KICA	SEQU	YOSE
Air and Climate	Air Quality	Ozone	✧	✧	●	●
		Airborne contaminants	✧	✧	✧	✧
		Atmospheric deposition	✧	✧	●	●
		Particulate matter	✧	✧	●	●
		Visibility	✧	✧	●	●
	Weather and Climate	**Weather and climate**	✚	●	●	●
		Snowpack	✚	●	●	●
Geology and Soils	Geomorphology	Stream channel morphology	✧	✧	✧	●
	Subsurface Geologic Processes	Caves/karst physical processes	-	●	✧	✧
Water	Hydrology	**Surface water dynamics**	●	✚	✚	✚
		Meadow/wetland water dynamics	✚	✚	✚	✚
	Water Quality	**Water chemistry**	✚	✚	✚	✚
		Toxics	✧	✧	✧	✧
		Snow chemistry	✧	✧	✧	✧
		Microorganisms	✧	✧	✧	✧
		Macro-invertebrates (meadows)	✧	✧	✧	✧
Biological	Invasive Species	**non-native plants**	-	✚	✚	✚

Level 1	Level 2	Vital Sign	DEPO	KICA	SEQU	YOSE
Integrity	Focal Species or Communities	*Selected plant communities*	✧	✧	✧	✧
		Forest stand population dynamics	✚	✚	✚	✚
		Phenology	✧	✧	✧	✧
		Meadow/wetland plant communities	✚	✚	✚	✚
		Amphibians	✚	✚	✚	✚
		Birds	✚	✚	✚	✚
		Cave biota	✧	✧	✧	✧
		Bats	✧	✧	✧	✧
		Meso-carnivores	✧	✧	✧	✧
Landscapes (Ecosystem Pattern and Processes)	Fire and Fuel Dynamics	Fire regimes	●	✚	✚	✚
		Fire effects on plant communities	●	●	●	●
	Landscape Dynamics	Landscape mosaics	✚	✚	✚	✚
	Viewscape	Night sky	✧	✧	✧	✧
	Soundscape	Soundscape	✧	✧	✧	✧
	Nutrient Dynamics	Biogeochemical cycling	✧	✧	✧	✧
	Energy Flow	Net primary productivity	✧	✧	✧	✧

Legend:

✚	Vital signs for which the Network will develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs.
●	Vital signs that are monitored by a network park, another NPS program, or by another federal or state agency using other funding. The Network will collaborate with these other monitoring efforts.
✧	High-priority vital signs for which monitoring will likely be done in the future, but which cannot currently be implemented because of limited staff and funding.
-	Vital sign does not apply to park, or for which there are no foreseeable plans to conduct monitoring.

3.2.3 Board of Directors Review

Following Science Committee selection of recommended vital signs, the Coordinator provided the Board of Directors (who oversee the coordinator and provide guidance to the Network) the following for review:

- description of the selection process
- list of the proposed final vital signs, as selected by the Science Committee
- short description of each vital sign, including its meaning and significance

At a one-day meeting on 29 August 2005, the BOD approved the Science Committee recommendations as the Network's final vital signs. At this meeting, the Coordinator reviewed the three items noted above, including soliciting input and direction. The BOD provided helpful critiques and discussion and expressed much satisfaction with the collaborative process that SIEN undertook to create and refine the list.

Regarding the final vital signs list, the Network Coordinator requested that the BOD recognize that

1. Minor changes to vital signs could be expected in the future.
2. As sampling protocol development commences during Phase III, some major changes may be requested for BOD approval, including addition or deletion of vital signs.
3. A strong possibility exists that the current list is outside the funding available through the Natural Resource Challenge.

Chapters 8-10 of the Phase III monitoring plan will address Network staffing, schedules, budgets, and leveraging necessary to implement the sampling protocols developed during Phase III. Given these considerations, the Coordinator requested that the BOD recognize that it would be approving the Network's final vital signs list as presented, with possible future modifications.

3.3 Vital Signs: Definition and Context

The Sierra Nevada ecosystem overview and broad monitoring objectives in Chapter 1 (section 1.5) and ecosystem conceptual models in Chapter 2 and Appendix I provide the primary framework and context for the reduced list of vital signs. The reduced list of vital signs is well-distributed across resource types—physical and biotic—and includes key drivers, stressors, and ecosystem processes. In this section we indicate the 33 candidate vital signs in context of the broad monitoring objectives outlined in Chapter 1 (Section 1.10) and provide specific descriptions and brief justifications for each vital sign.

Next in this chapter, for the 12 vital signs selected for protocol development in the next two years, we also present specific descriptions, significance, and more specific monitoring objectives. At the end, we provide our plans for evaluating and potentially pursuing the italicized vital signs (from Table 3-3) in subsequent years.

3.3.1 Relationship of Vital Signs to Broad Monitoring Objectives

The Sierra Nevada ecosystem overview and broad monitoring objectives in Chapter 1 and the ecosystem conceptual models in Chapter 2 and Appendix I provide the primary framework and context for our key list of vital signs. This "smaller" list of vital signs is well-distributed across resource types—physical and biotic—and includes key drivers, stressors and ecosystem processes. In this section, we indicate the primary candidate vital signs in context of the broad monitoring objectives outlined in Chapter 1 (section 1.10).

Objective 1: Understand the natural range of variation in annual and seasonal weather patterns, long-term trends in climate, and effects of global climate change on hydrologic regimes and biological processes.

Key vital signs include

- **Weather and climate**
- **Snowpack**
- **Surface water dynamics**
- **Meadow/wetland water dynamics**
- *Phenology*

Objective 2: Understand patterns of spatial and temporal variation in fire regime characteristics and relationships to changes in climate and vegetation.

Key vital signs include

- **Fire regimes**
- Fire effects on plant communities
- Landscape mosaics

Objective 3: Understand patterns of temporal and spatial distribution of air-borne pollutants, and their effects on aquatic and terrestrial systems.

Key vital signs include

- **Water chemistry**
- *Airborne contaminants*
- *Atmospheric deposition*
- *Toxics*
- Particulate matter
- Snow chemistry
- Ozone

Objective 4: Understand natural patterns of variation in hydrology and how these processes respond to changes in climate and fire regime.

Key vital signs include

- **Surface water dynamics**
- **Meadow/wetland water dynamics**
- Cave/karst physical processes
- Stream channel morphology

Objective 5: Monitor water quality and the response of native aquatic biota to changes in chemical and physical properties of aquatic systems.

Key vital signs include

- **Water chemistry**
- **Amphibians**
- *Microorganisms* (and macro-invertebrates)
- Cave biota
- Biogeochemical cycling

Objective 6: Understand compositional and structural patterns of plant communities and their distribution on the landscape.

Key vital signs include

- **Alien invasive plants**
- **Landscape mosaics**
- Selected plant communities
- Fire effects on plant communities

Objective 7: Document rates and types of change in plant communities in response to environmental factors and human effects.

Key vital signs include

- **Landscape mosaics**
- *Phenology*
- Selected plant communities
- Forest stand population dynamics
- Fire effects on plant communities
- Net primary productivity

Objective 8: Understand the ecological relationships between terrestrial landscape elements and animal distributions.

Key vital signs include

- **Meadow/wetland plant communities**
- **Birds**
- *Selected plant communities*
- *Bats*
- Cave biota

Objective 9: Document rates and types of change in animal communities in response to changes in landscape characteristics, biotic interactions, and ecosystem stressors.

Key vital signs include

- **Amphibians**
- **Birds**
- Macro-invertebrates (meadows)
- *Bats*
- *Microorganisms*
- Meso-carnivores (mid-sized)

Objective 10: Monitor resources that have been identified as having unique values to the network parks. These resources may or may not be the best indicators of ecosystem condition, but are valued in and of themselves.

Key vital signs include

- Night sky

- Visibility
- Soundscape

Objective 11: Monitor trends in the distribution and abundance of focal species.

Key vital signs include

- **Amphibians**
- **Birds**
- Giant Sequoia (a component of **Forest Stand Population Dynamics**)
- *Bats*
- Lichens (a component of *Plant Communities*)
- Meso-carnivores (mid-sized)
- Cave Biota

3.4 How SIEN Will Monitor Vital Signs

It will be necessary to employ a wide variety of techniques and approaches for monitoring vital signs. SIEN has not yet determined the best technique(s) for measuring all its vital signs to achieve stated objectives. However, such monitoring will include a mixture of field-based, automated, laboratory and remotely-sensed methods. Measurements will be made at a variety of spatial and temporal scales; not all vital sign variables need to be measured every year (e.g., landscape mosaics), while others may require measurements every hour (e.g., stream flow).

Techniques and approaches for monitoring vital signs are presented in Chapter 4. Specific variables, measures, and parameters, where determined, are described in Vital Sign Protocol Development Summaries (Appendix K).

Chapter 4 SAMPLING DESIGN

> "Spatially balanced monitoring is the collection and analysis of repeated observations or measurements over a long period of time to document the status and trend of ecological parameters."
>
> —The National Park Service

(This chapter is adapted from Upper Columbia Basin Network, Central Alaska Network, and Greater Yellowstone Network monitoring plans.)

4.1 Monitoring Programs and Sampling Design

Monitoring programs must provide unbiased and useful statistical estimates of the status and the changes in ecosystems across large areas or entire study sites. Unlike most short-term research, monitoring programs do not try to answer a single question nor test a specific hypothesis. Instead, they enable us to understand a broad and wide range of long-term hypotheses by uncovering correlations and patterns between ecological parameters and external factors. Although they do not establish cause and effect relationships (e.g., anthropogenic impact on the status of an ecosystem), they do show us a *big picture* of ecosystem dynamics, which can suggest experiments that test more specific hypotheses.

Because of its long-term nature (i.e., *decades*), monitoring programs incorporate sampling designs that focus on the properties of an ecosystem that are 'easy to measure' while still being meaningful and helpful to researchers and managers. These measurements should be repeatable and allow inference from smaller to larger areas. Although we typically want immediate results, we need patience to wait for more complete information that will allow us to make better decisions about preserving species and habitats. Long-term studies also require consistent motivational and financial support, as well as well-considered sampling designs.

This chapter presents an overview of the general approaches SIEN has taken to develop sampling designs for its suite of vital sign monitoring protocols scheduled to be implemented during the next five years. Table 4-1 (at the end of this chapter) summarizes basic design decisions that have been made to date (i.e., December 2006). Specific design and decision justifications are included in individual vital sign monitoring protocol development summaries presented in Chapter 5, as well as in our vital sign monitoring protocols (*in development*).

We begin with an overview of basic concepts and terminology, and then discuss specific SIEN vital sign design strategies.

4.2 Sampling Design

Sampling designs, within the context of the Sierra Nevada Network's monitoring program, encapsulate the series of decisions that dictate where, when, and how to sample a vital sign's indicator (e.g., the indicator nitrate as a measure of lake water chemistry)(Elzinga et al. 2001). Their paramount purpose is to ensure collection of representative data of adequate scope to support defensible inference and draw conclusions about a population of interest. But deciding how to sample is often difficult because of the trade-offs between costs and benefits. Thus, any sampling design represents a balance between idealized objectives and the practical constraints of cost, time, logistics, safety, and existing technology.

We also must make numerous practical and statistical decisions to ensure confidence that our sampling design and indicator measurements are providing the vital sign information we need (Busch and Trexler 2003). The following questions can help us make those decisions

- What are the defining boundaries of the ecological system?
- What is the appropriate temporal frame for sampling?
- What is the appropriate time interval between samples?
- What sample size is necessary to estimate the value of the indicator?
- What survey design is most efficient (random, systematic, stratified random)?
- What is the appropriate unit of measure for the indicator variable?
- Is there an optimal sample unit size and shape for estimating the value of the indicator?
- What are the trade-offs between gains in precision and statistical power and the additional costs per sample?
- How can the monitoring program best be designed so that sources of uncertainty about the true state of the ecological system are minimized?

We address many of these questions in this chapter, including those involving target populations and sampling frames (Figure 4-1), allocation and arrangement of samples (*membership design*), frequency of sampling occasions (*revisit design*), measurements to be taken at sampling locations (*response design*), and the number of samples required to meet stated objectives (*sample size*). Italicized terms are described later in this chapter. We also discuss SIEN strategies for integrating sampling designs for groups of vital signs. To insure continuity among projects and consistency in data collection and analysis, we adhere to sample design guidelines of the national NPS Inventory & Monitoring program (http://science.nature.nps.gov/im/monitor/SamplingDesign.cfm).

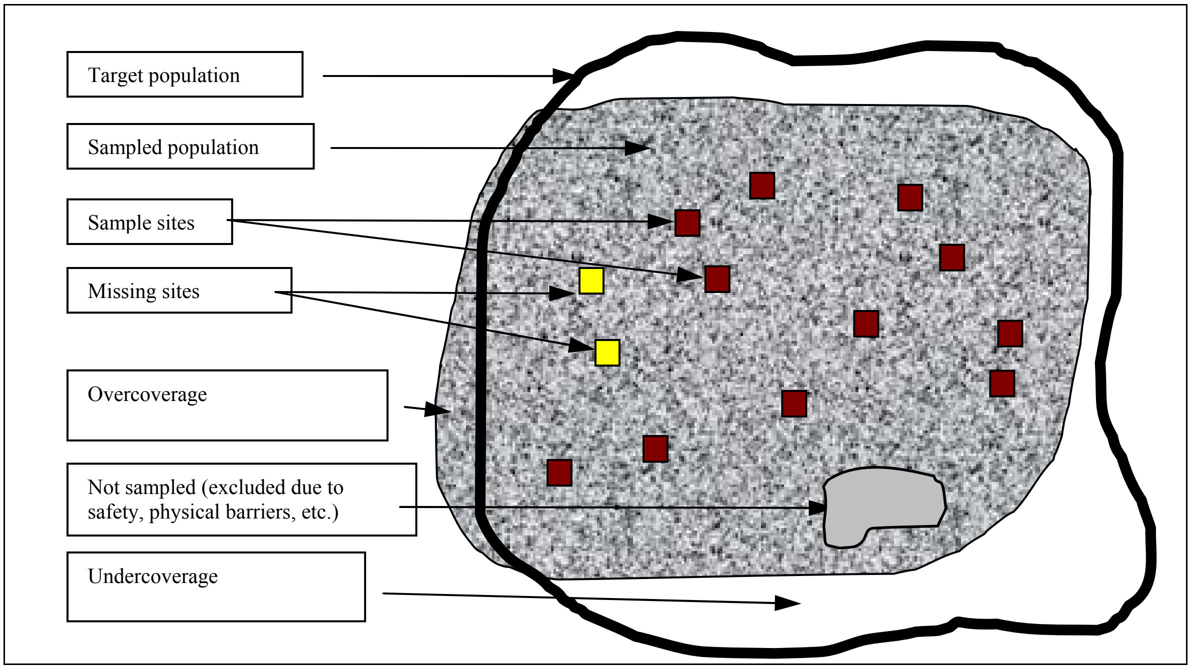


Figure 4-1. Conceptual illustration of terms used to describe various units associated with sampling a population of interest.

4.3 Sampling Design—Conceptual Framework

A good sampling design is based on clear and concise monitoring objectives. The development of the design is an iterative process—as we continue to refine our objectives, we gain new insights into particular vital signs and the needs of park management. Sampling designs must be flexible. Because our intent is to develop a robust monitoring program that can meet the needs of NPS managers well into the future, our designs must be able to accommodate changes in management and funding priorities, as well as environmental changes. Thus, our monitoring objectives must balance the needs of current park managers and future generations of managers who can expect environmental and management challenges we cannot foresee now.

A good sampling design should be appropriately concise, understandable, and manageable. Overly complex designs can be confusing and may reduce accessibility by the monitoring program's key audience—park managers and superintendents—many of whom are not well versed in statistics and sampling design theory. Therefore, we have attempted to design our SIEN monitoring program by starting simply and adding complexity conservatively and only when needed to achieve objectives. Of course, to monitor ecosystem structure, function, and processes, some level of complexity cannot be avoided, particularly when dealing with large, remote, and difficult-to-access landscapes (McDonald and Geissler 2004).

As discussed in Chapters 1 and 3, our monitoring objectives call for the estimation of *status*, *trend*, or both. We are intentional in our use of those two terms and follow definitions reviewed by (Urquhart et al. 1998) and(McDonald 2003). **Status** is a measure of a current attribute, condition, or state, and is typically measured with population means. **Trend** is a measure of directional change over time and can occur in some population parameter such as a mean (*net trend*), or in an individual member or unit of a population (*gross trend*). Status applies to specific points in time, whereas trend pertains to measurements across multiple time periods. Status typically is served best by a spatially extensive sample size, while trend is less reliant on large samples. This sets up the first cost-benefit decision, and is one that must be addressed through a careful consideration of program objectives.

The next important step when developing a sampling design is to define the collection of animals, plants, natural resources, or environmental attributes of interest within a specified study area (Figure 4-1). A population consists of **elements**, i.e., the objects on which a measurement is taken. (Scheaffer et al. 1990). This is the basic "unit" of observation. A **target population** is defined as the complete collection of units to which inference is made. Note that this is a statistical population and it may or may not refer to a biological population.

Sampling unit refers to the unit actually sampled; they are non-overlapping collections of elements (in most cases, the sampling unit is the same as the element). We try to quantify our target population by using a **sampling frame**, defined as the collection of sampling units. Common examples of sampling units in SIEN's monitoring program include plots, quadrats, and pixels on a digital map, or discrete phenomena such as lakes, meadows, or stream segments. A **sample** is a subset of units chosen to record a response through counts, observation, or other form of measurement. If the sample is generated using some type of random draw, the sample is said to be a **probability sample**.

Whenever possible we have used a probability sample to monitor SIEN vital signs. We prefer probabilistic sampling designs because they permit valid inference to the sampled population, whereas non-random judgment sampling allows inference only to individual sampling units. In some situations, for example when a small park boundary contains only a trivial fraction of all river reaches within a watershed (e.g., portions of San Joaquin River and watershed within Devils Postpile), it might be appropriate to use non-random judgment sampling. We might also use non-random sampling to locate index sites (described below), which can be helpful in determining trend, despite limited statistical scope of inference.

Because SIEN parks are typically quite large, probabilistic sampling is being employed for most vital signs (see below: membership design); judgment sampling may be appropriate for some vital signs in some locations. In addition, because of the size and topographic complexity of our parks, it may be necessary and efficient to **stratify** sampling based on elevation or ecosystem characteristics (e.g., lake versus pond, wet versus dry meadow). Another alternative to probabilistic sampling used in the SIEN program is the **census**, which involves obtaining a response from every element in the target population. However, an adequate sampling frame and survey design that ensures a census is actually obtained is necessary to obtain a census that is free of frame error. Though rarely possible in most ecological applications, it can occur, for example, with the use of satellite imagery to determine land cover change. Satellite imagery may also contain sources of frame error depending on the pixel resolution and the temporal frequency of images used to detect change.

Non-sampling error may affect the precision and accuracy of estimates from these surveys (Lessler and Kalsbeek 1992). **Frame error** is the error resulting from the disparity between the target population and sampled population. Over-coverage occurs when the sampled population contains elements not included in the target population. Under-coverage occurs when elements of the target population are omitted from the sampled population. **Non-response error** results from the failure to obtain responses for the entire chosen sample. When missing outcomes are very different from the outcomes obtained, the estimates calculated from the responding portion of the sample may be biased. **Measurement error** is defined as the difference in measurements obtained and the true value of the measure and may include detection errors from observers and instrument errors. The three components of non-sampling error may not always be avoidable, but survey planning and design that accounts for these error sources may be helpful in reducing the effects of non-sampling error.

Once the target population and sampling frame have been determined, a strategy for drawing samples, allocating them appropriately across the sampling frame, and timing visits for sampling is determined. Most sample designs proposed for SIEN will rotate field sampling efforts through various sets of sample units over time. In this situation, it is useful to define a **panel** of sample units to a group that is always sampled during the same sampling occasion or time period (Urquhart and Kincaid 1999, McDonald 2003). See Figure 4-2 for a schematic representation of, and notation for, different revisit designs.

The way in which units in the population become members of a panel will be called the **membership design** (McDonald 2003). Membership design specifies the spatial allocation procedure. One familiar membership design strategy is simple random sampling, the procedure which involves drawing units from a population at random with equal probability. Unfortunately, this often fails to produce an ideal spatial sample in ecological settings because of uneven spatial patterns inherent to any particular simple random draw and concordant environmental spatial patterns. In particular, simple random samples generated from a population can often be patchy or clustered, with groups of sample sites closer to one another than to other groups of samples, and large areas of the frame can remain unsampled. An alternative, and one that the SIEN is proposing to use in most of its vital signs requiring a probabilistic sample, is to draw a spatially-balanced random sample following the methods described by (Stevens Jr. and Olsen 2004). These approaches allow for a spatially-balanced random draw of samples with variable inclusion probabilities and an ordered list of samples that can support additions and deletions of samples while retaining spatial balance. These features provide considerable flexibility and efficiency to the SIEN program.

Index sites—also known as *sentinel* or *intensive* sites—are sampling locations that are (i) visited either more frequently, (ii) are sites where more detailed measures are made, or (iii) both. Conversely, a **survey** (or *extensive*) site is one where visits to collect data are less frequent, or where less detailed measures are obtained. Generally, “always” visiting a sampling site is strongest for detecting temporal variation (or trend), but is weak for detecting spatial variation. Conversely, less frequent visits, coupled with visitation to more sampling sites, will provide more data on the status of a resource.

Once samples are drawn, we assign them to panels and schedule them for revisits over time. Panels can be constructed in various ways. Currently the SIEN is proposing to include all samples from our smallest park, Devils Postpile, as one panel. In the case of our larger parks–Sequoia & Kings Canyon and Yosemite–multiple panels may be required to cover entire park landscapes of interest. The temporal scheduling of sampling, particularly when multiple panels are being used, requires a **revisit design** (Urquhart and Kincaid 1999, McDonald 2003).

SIEN has adopted (McDonald 2003) notation for revisit designs for brevity and consistency. Under this notation, the revisit plan is represented by a pair of digits. The first is the number of consecutive occasions that a panel will be sampled, and the second is the number of consecutive occasions that a panel is not sampled before repeating the sequence. The total number of panels in the rotation design is normally the sum of digits in the notation. For example, using this notation the digit pair [1-2] means that members of three panels will be visited for one occasion, not visited for two occasions, then visited again for one occasion, not visited for two occasions, and so on. If a single panel is to be visited every sample occasion, its revisit design would be [1-0]. The notation [1-1] indicates that a panel is to be sampled on an alternating schedule. The notation [1-n] means a panel is to be visited once and never again. The notation [1-0,1-5] means that units in one panel will be visited every occasion, while units in six other panels will be visited once every six years. We call this particular design a **split-panel**.

Both **response design** (measurements taken at sampling locations) and **sample size** (the number of samples required to meet stated monitoring objectives), two essential components of any sampling design, are detailed in the protocols themselves (see overview, Chapter 5), but we introduce them briefly in this chapter. Response design and sample size components are developed after basic decisions regarding target and sampling population, spatial allocation and membership, and revisit strategies have been made. In addition, a response design is usually necessary before sample size can be estimated appropriately. This is particularly true when response decisions, such as plot shape and size, strongly influence the variability of population estimates. However, we must decide about sample size in order to finalize decisions about membership and revisit design, and in practice, sampling designs arise out of an iterative process and the order of operations is not rigid. As with the design decisions described above, sample size is primarily an exercise in cost-benefit trade-offs, and must be determined through careful consideration of program objectives.

Panel	1	2	3	4	5	6	7	8	9	10
Design [1-0]										
1	X	X	X	X	X	X	X	X	X	X
Design [1-n]										
1	X									
2		X								
3			X							
4				X						
5					X					
6						X				
7							X			
8								X		
9									X	
10										X
Design [2-n]										
1	X									
2	X	X								
3		X	X							
4			X	X						
5				X	X					
6					X	X				
7						X	X			
8							X	X		
9								X	X	
10									X	X
Design [2-3]										
1	X	X				X	X			
2		X	X				X	X		
3			X	X				X	X	
4				X	X				X	X
5					X	X				X
Design [1-0, 2-3]										
1	X	X	X	X	X	X	X	X	X	X
2	X	X				X	X			
3		X	X				X	X		
4			X	X				X	X	
5				X	X				X	X
6	X				X	X				X

Sample Occasion

Figure 4-2. Examples of five different revisit designs, beginning with the simplest, in which a single panel or set of sampling units are visited on every sampling occasion, and ending with a complex split-panel design in which the first panel is sampled on every occasion and five panels are revisited on two consecutive occasions and then "rested" for three occasions.

4.4 Sample Size Considerations and Magnitude of Change

Populations in the real world are dynamic; change over time is to be expected. However, what is important is whether or not there has been *meaningful* change (meaningful to the ecosystem, public, or park manager), what has caused the observed change, and whether or not the resource you are monitoring is expected to change further.

To understand what constitutes a meaningful and significant change, we must differentiate between statistical significance and biological significance. Statistical significance relies on probability and is influenced by sample size. Thus, even minor changes (from a biological perspective) will be statistically significant if the sample size is large enough. So, regardless of statistical significance, we would consider something biologically significant if it facilitates a major shift in ecosystem structure or function (e.g., loss of one or more species, addition of non-native species, changes in ecosystem processes, etc.).

Thus, from a monitoring standpoint, we are concerned with both statistical and biological significance. We want to know whether we are likely to detect a change statistically that we also consider biologically meaningful. To answer this we need to decide what level of statistical significance we want to attain (i.e., our Type I error rate or α, discussed below), what level of change do we consider biologically meaningful and that we hope to detect, and how variable is the indicator measure we are trying to estimate.

In addition to our monitoring objectives, we need to define our **sampling objective.** Sampling objectives establish a desired level of statistical power, the capacity to detect a 'real' change or trend, a minimum detectable change or effect size, and acceptable levels of both a false-change (α or the probability of a Type I error) and a missed-change (β or the probability of a Type II error)(Elzinga et al. 2001). Sample size is a function of each of these components, and decreasing sample size, which can be desirable for cost effectiveness, will often force acceptance of higher error and lower power. These trade-offs are mitigated by reducing variance estimates, either through modifications in response design, another component (e.g., revisit design), or by accepting a higher minimum effect size (Steidl et al. 1997).

In general, sample size should be large enough to give a high probability of detecting any changes that are of management, conservation, or biological importance, but not unnecessarily large (Manly 2001). Scientists traditionally seek to reduce Type I errors, and accordingly prefer small alpha levels. In a monitoring program such as ours with a strong resource-conservation mandate, however, it is preferable to employ an early-warning philosophy by tolerating a higher alpha, but consequently increasing the power to detect differences or trends (Sokal and Rohlf 1995, Roback and Askins 2005).

Accordingly, SIEN has conservatively adopted minimum standards of an *alpha of 0.10 and power of 0.80*, which will enable us to detect magnitudes of change of ≥20%, in agreement with national NPS I&M approaches. For some vital signs and measures, we will be able to significantly reduce these minimum standards with acceptable increases in cost.

For our initial set of protocols, we will use *a priori* power analyses to determine the approximate sample size needed to detect meaningful (≥20%) levels of change. Given our specification of alpha, desired power, and effect size, combined with information on the variance of the response variable in question (obtained from available data or comparable analogous data, where available), it is possible to calculate the sample size required to achieve these results. Statistical power analysis (Gerrodette 1993)1987, Lewis 2006) is the typical approach to estimating sampling sizes for monitoring population trends.

We may use existing software programs (e.g., (Gerrodette 1993) and simple equations (Elzinga et al. 2001, Manly 2001) for approximating sample sizes. For more sophisticated power analyses based on simulations, we will work with our statistician and use more powerful programs (e.g., SAS software, SAS Institute, Inc.; and R programming language http://www.r-project.org/). In addition, SIEN is working with one or more statisticians intimately connected to colleagues who are further developing these and other tools to meet the needs of I&M monitoring programs. Further, we will recalculate sample sizes periodically for individual vital signs as data become available in order to refine and revise sampling designs and ensure that objectives are being met.

4.5 Integration of SIEN Vital Signs

Integration of SIEN vital signs will first occur during protocol design, and will continue during data collection, data management, data analysis, and reporting phases. This integration will occur within individual protocols, among protocols, and between the Sierra Nevada Network and partner programs.

4.6 Integration of Fieldwork

NPS guidelines for developing an integrated monitoring program encourage co-location and co-visitation of sampling sites. Currently, we are designing several of our protocols to simultaneously collect data for more than just a single vital sign (Table 4-1), such that they will be sampled at the same place (**co-location**) and time (**co-sampling**). Resulting information will provide a more holistic, ecological assessment for integrated vital signs.

One example of this approach is the development of our Meadow Ecological Integrity Monitoring Protocol, which will integrate aspects of the following vital signs: selected vegetation communities–*i.e.*, meadows, wetland water dynamics, and invertebrates. In addition, during data collection for the vegetation monitoring aspect of this protocol, we will also have the opportunity to monitor meadows for early detection and trends in target invasive plants in order to meet objectives for that vital sign.

We will also take an integrated approach with our Lake Monitoring Protocol, integrating aspects of data collection for the following vital signs: water chemistry, surface water dynamics, and amphibians. We will acquire remotely sensed data for our land cover/land use protocol to support information necessary for our fire regime, climate, and forest dynamics vital signs. Ground-truth data will support the remote sensing products and directly link the two data sets.

Integration will also occur between SIEN monitoring and other national and regional monitoring programs. Water chemistry, for example, will be monitored in a way that yields statistically robust results for each park, yet these data will also be comparable with other national and regional programs. Such data will be integrated when it is scientifically valid to do so. Some of these programs have accumulated data for many years at a large number of sites around the Sierra Nevada, including sites near SIEN parks. Integration at this level will provide a regional context for many SIEN vital signs.

While some integration is planned for several of our vital signs, others are not well suited for co-location and co-visitation because they do not exhibit strong spatial or temporal links. In addition, the decision of whether to integrate also depends on the following: (1) whether it is ecologically appropriate for the metric(s) being monitored, (2) whether it is statistically appropriate (in terms of sample size and spatial allocation), and (3) whether it will affect the quality of other data being collected at those locations. Opportunities for integration of additional (i.e., Tier 2) vital signs may be realized during the first years of our monitoring program (e.g., phenology as part of meadow ecological integrity; glaciers, as part of landscape mosaics).

4.7 Integration of Data

We will integrate analysis and interpretation approaches among protocols where possible. In Chapter 2, we present conceptual models illustrating links among vital signs. These links are based on known or proposed relationships among stressors, ecological processes, vital signs, and other factors that operate across spatial and temporal scales.

In Chapter 3, we discuss our broad monitoring objectives for elucidating the relationships among SIEN vital signs, for example, how to

> *1. understand natural patterns of variation in hydrology and how these processes respond to changes in climate and fire regime*
>
> *2. monitor water quality and the response of native aquatic biota to changes in chemical and physical properties of aquatic systems*

By using data collected within and among protocols, we can assess the presence and strength of these relationships using a diversity of statistical techniques, ranging from simple correlations to structural equation models. We note, however, that the primary goal of the protocols was to develop statistically sound monitoring methods; conversely, tests of causality would require a very different sampling design. That stated, it is still feasible to use GIS-based analyses, simple linear models, and perhaps more advanced techniques (e.g., multivariate analyses) to quantify relationships noted in our conceptual models. These statistical approaches are described more fully in Chapter 7.

4.8 Overview of Sampling Designs for SIEN Vital Signs

Our proposed approach to developing sampling designs for monitoring vital signs is outlined below. Designs will be modified as protocol development continues. As of this Phase III Monitoring Plan draft (circa December 2006), SIEN staff are currently working with statisticians at the University of Idaho and Oregon State University to develop detailed sampling designs for several vital signs: water quality, surface water dynamics, amphibians, and landbirds. Over the next five years, the Sierra Nevada Network will develop nine monitoring protocols (discussed in Chapter 5) comprising the vital signs listed below.

4.8.1 Water Chemistry

A map showing waterbody locations will be provided at a future point in protocol development. Such map will show the location of index sites, and include the larger "sampled population" (i.e, survey sites that are part of our sampling frame). Until peer review of the protocol is completed, the generation of random sample sites is premature.

Water chemistry will be measured in Sierra Nevada Network lakes, rivers, and streams. We are currently developing the sample design for lake water chemistry monitoring. We are integrating sampling with surface water dynamics and amphibian vital signs. The approach for river and stream monitoring will not be developed until 2007-2008.

Our network, along with others working in large mountainous landscapes, have struggled with the trade-offs between in-depth temporal sampling and the ability to make inferences across the landscape. We hope to achieve a balance by applying different sampling frequencies to different sites—survey sites and index sites. We still have many details to consider for a sample design, but an example of the type of design we could implement is a spatially-balanced probabilistic design using a rotating panel. Index sites, which will be sampled more frequently, may be selected using criteria such as accessibility, existing monitoring or research, and specific management concerns.

The target population for inference on water chemistry in Sierra Nevada Network lakes includes all lakes in the network that are over 8 hectares in area or at least 2 m in depth. Since no lakes occur in Devils Postpile, the target population for the network only includes lakes in Sequoia, Kings Canyon, and Yosemite. The sampling frame will be a GIS coverage from the National Hydrography Dataset which enumerates all lakes within the park. Strata may be formed based on accessibility (specifically distance from the closest trail) or geology. Inference at the park and network level is desired, so if budgets allow, the survey design may treat the parks as strata so that inference at the park level is possible. The sampling unit for this survey will be lakes, with responses taken within lakes. Response design is still under development. Currently, the response design is planned to include taking measurements at the center of the lake and at the outlet. When lakes are well mixed, these measurements will be quite comparable. However, when lakes are stratified and vertical temperature gradients exist, multiple measurements may be taken at the lake's center.

Several measurements will be taken at each point. Probe measurements will be made to measure temperature, specific conductance, and dissolved oxygen. Water samples will be taken and stored for laboratory examination, and these samples will provide measurements for several constituents. When lakes are not well-mixed, these sets of measurements may be taken at multiple depths. Surveys will be conducted to obtain estimates of status and trend. Status measurements will include measures of lake characteristics and the proportion of lakes above a certain threshold value (to be determined). Trends of chemical concentrations and ratios of constituents will also be of interest.. Because status is of interest, random samples will be selected using a GRTS design to ensure spatial coverage of lakes within parks. A rotating panel design may be used so that trend may be estimated over time. Tradeoffs between replication in space at a given time for status and replication over time for trend will be explored.

Index sites will be used to monitor sites of particular interest, based on existing research and monitoring, accessibility or demonstrated sensitivity to certain stressors.. These index sites will be visited more frequently, for instance once or twice a month, from spring through fall. Additional instrumentation will be used at index sites so that continuous data collection is possible. These sites will be used to estimate inter-and intra-annual variability; however, care will be taken in comparing these sites to randomly-selected sites since the index sites will constitute a judgment sample.

If a large number of observers cannot be obtained to collect samples at different lakes concurrently, then a smaller crew will have to survey all of the lakes sequentially. This will confound results in space and time within a survey season. Survey seasons and scope are limited by spring snow, stream crossings, weather, and issues related to wilderness designations. Furthermore, when water samples are collected, these samples must be delivered to the laboratory within a certain time period. This will affect the length of time that crews can remain afield.

Non-sampling error may affect estimates derived from data collected during these surveys. Frame error may be generated by error in the maps used to create the sampling frame. Lakes that are close to 8 ha in area or 2 m in maximum depth may be included or excluded in the sampling frame, in error. However, this error is not expected to be large or consequential in estimation and inference. Non-response error may occur if survey crews have difficulty in accessing a lake or encounter harsh environmental conditions. Obtaining spatially balanced samples with alternative sites may decrease the error due to non-response if alternate sites are representative of sites missed due to site inaccessibility. Occasionally, water samples are damaged or contaminated or laboratories have problems obtaining measurements. Quality control and assurance programs help us track why these problems occur and enable us to determine the appropriate methods to account for non-response. Measurement error can occur when observer crews are not properly trained or instrumentation fails. Observer crews may possibly misuse probes during surveys or introduce subjectivity into measurement processes when lakes are stratified and multiple samples are taken. Below-detection-limit data may be obtained during chemical analyses in which instrumentation fails to obtain a response.

A wealth of data is available for sample size approximation and power analysis. Fall lake chemistry data is available from the EPA's 1985 Western Lake Survey and Clow et al.'s 1999 resurvey (Clow et al. 2003). Over 20 years of data are available from research and monitoring conducted at Emerald Lake. Ultimately, managers need temporal data over a broader spatial scale for trend analysis at a wider scale. Sources of variation include seasonal and annual variability; spatial variability by geology, position within a valley, and vegetative cover within the watershed; and how well-mixed lakes are when measurements are taken. Stressors will also affect variability of measurements taken in lakes, specifically variation due to climate, climate change, atmospheric deposition including nitrogen deposition pulses in the spring, non-native species, and human use.

4.8.2 Surface Water Dynamics

Refer to water chemistry section for a description of the sampling design approach.

Surface water dynamics will be measured in Sierra Nevada Network lakes, rivers, and streams. We are integrating this vital sign with water chemistry. We are currently developing the sample design for lake monitoring; the approach for river and stream monitoring will not be developed until 2007-2008.

4.8.3 Amphibians

SIEN's science committee has decided that fiscal and logistical limitations necessitate the exploration of integration of amphibian monitoring with lake chemistry monitoring. We do not know if this will meet our amphibian monitoring or sampling objectives, and details regarding sample design and probability of inclusion for amphibian populations have not been worked out yet; discussions are occurring between the two vital signs at this time. We are working with our statistician to see if integration can be achieved. However, we have not yet conducted data analyses to assess the practicality of integration. If feasible, we will include lakes with a history of long-term amphibian monitoring in the lake water chemistry sample population.

SIEN has identified existing datasets that could be resources for power analysis and sample design; scientists have been conducting anuran research and monitoring in Sierra Nevada parks for over a decade. Detailed GIS coverages encompassing a wealth of recent amphibian data exist for both SEKI and YOSE.

In addition, SIEN met with the USFS Sierra Nevada amphibian monitoring team lead to discuss collaboration with the USFS. The USFS within the Sierra Nevada has developed a GRTS-based, peer-reviewed monitoring protocol for mountain yellow-legged frogs and Yosemite toads that has implemented over the past five years across all Sierra Nevada national forest lands (Brown 2001). Full collaboration between NPS and USFS would be cost-effective, and would provide a complete regional picture of the status and population trends of these declining amphibians across lands with varying management practices. Amphibian measures (e.g., abundance of anurans) would be collected at both index and extensive sampling sites, for park-level inference on trends and abundance. Further, data will be collected in a manner which could allow data-sharing within context of the larger USFS effort, resulting in an influential and powerful partnership for conservation of Sierra Nevada amphibians. We are working with our statistician to ensure SIEN objectives for amphibian monitoring are met, and opportunities for data sharing with USFS are evaluated.

Our current target population includes populations (historic and extant) of mountain yellow-legged frog (*Rana muscosa*), Yosemite toad (*Bufo canorus*); and Pacific treefrog (*Hyla regilla*) in SEKI and YOSE. Decisions for sampling amphibians in DEPO have not been made; only one of our target species (Pacific treefrog) occurs there.

Details regarding sample design and probability of inclusion for amphibian populations has not been worked out yet. Detailed GIS coverages encompassing a wealth of recent amphibian data exist for both SEKI and YOSE. Large and extensive datasets are available for amphibians, both from the parks themselves (e.g., up to ten years at one site in Yosemite), and also from surrounding USFS long-term monitoring. Occurrence of amphibian species and relative number of adults and tadpoles would be recorded.

4.8.4 Climate

Unlike most other vital signs, various measures of SIEN park climate have been monitored for the last century. Currently, an existing network of monitoring stations is maintained by a variety of state and federal agencies and universities within and adjacent to the parks. Most existing sites were selected using best professional judgment of that time; changes to existing sites would severely compromise existing legacy climate data from these stations. Our basic approach involves a detailed analysis of existing climate monitoring stations to determine whether they provide adequate sampling of spatial and temporal variability and adequate data for strata of management interest or scientific importance. We will use the results of this analysis to determine how the network can best contribute to the current system.

4.8.5 Wetland Water Dynamics

A similar sampling design will be utilized for three vital signs: (1) wetland water dynamics, (2) meadow and wetland ecological integrity (vegetation); and (3) invertebrates.

The target population for inference on meadow and wetland ecological integrity includes approximately 12,000 wetlands in SEKI and YOSE; only a single wetland complex occurs in DEPO. The sampling frame is basically equivalent to the target population. We plan on using a GIS coverage of California watersheds. In addition, we may use park DEMs to refine our watershed boundaries. Approximately 6 to 8 watershed types will be classified using cluster analysis (e.g., based on surface bedrock geology, glaciation history, source of precipitation, elevation, soil type). Coverages to be used for wetland classification include GIS and other maps, e.g., NWI, vegetation maps, aerial photography. Wetlands will be classified into approximately four strata: wet meadow, fens, riparian, and marsh.

The sampling unit for this survey will be a quadrant within strata, based on wetland and watershed types. We have several response types: a well (at sentinel/index sites; survey sites may have wilderness issues that prevent well installation), a vegetation plot or transect, and a net-sweep for vertebrates. Currently, the response design is planned to include taking measurements at a well, and in plots and subplots. Several measurements will be taken: water level at the well, including temperature and electrical conductivity; vegetation cover and species composition in plots (plot size may vary depending on response unit, e.g., larger plots for trees and shrubs, and smaller plots for herbaceous plants); numbers of individuals per vertebrate taxon and species composition; and geomorphology (e.g., distance of well from nearest stream).

Surveys will be conducted to obtain estimates of status and trend. Status measurements will include measures of changes in water (seasonal and long-term), plant species composition (cover), and relative abundance of invertebrates. We are also interested in trend of meadow condition, with desired estimate of detection of a 20% change over a decadal time frame at 80% power.

Because status is of interest, random samples will be selected using a two-stage GRTS design to ensure spatial coverage: (a) of watersheds, and (b) wetland type within watersheds. A rotating panel design may be used so that trend may be estimated over time. Tradeoffs between replication in space at a given time for status, with replication over time for trend, will be explored.

Survey sites will be visited annually, each summer, based on hydrologic cycle. Index (or sentinel) sites will be used to monitor sites of particular interest—chosen based on accessibility, history of research at the site, ability to install instrumentation because site is not subject to Wilderness Act concerns, etc.. Survey seasons and scope are limited by spring snow, stream crossings, weather, and so on.

Index sites will be visited more frequently, from mid-May through October. These sites will be used to estimate inter-annual variability (e.g., vertebrates); however, care will be taken in comparing these sites to randomly-selected sites since the index sites will constitute a judgment sample. Field crews will hike to selected meadow/wetland polygons; some pack stock or helicopter transport of equipment may be necessary.

Several non-sampling error sources may affect the precision and accuracy of estimates from these surveys. Frame error, while thought to be low, may be generated by error in the maps used to create the sampling frame. Stratification error may be high, related to wetland type—it is also acknowledged that a wetland polygon could actually be comprised of several different types of wetlands, juxtaposed; this will be reevaluated after first field season. There is a minimal chance of instrumentation failure (e.g., well monitor), or that a crew would be unable to get to a site (safety or weather concerns are minimal, but acknowledged). Obtaining spatially balanced samples with alternative sites may decrease the error due to non-response if alternate sites are representative of sites missed due to site inaccessibility.

We can use quality control and assurance programs to track why these problems occur and determine the appropriate methods to account for non-response. Measurement errors can occur when observer crews are not properly trained or instrumentation fails. Observer crews may possibly misidentify of plants, but protocols will be implemented to minimize this error.

Both quadrat and transect data are available to inform plot sample size approximation and power analysis of meadow/wetland vegetation. We have several years of invertebrate data from our work supporting development of this monitoring protocol. Our existing data provide a baseline for variability of a site; we have some data to inform spatial variability. We may have some well and vegetation data to inform power to detect trend, but data are not available for vertebrates.

Ultimately, managers need temporal data over a broader spatial scale for trend analysis at a wider scale. Sources of variation are highest for vertebrates and include seasonal and annual variability, including that influenced by wet years and dry years. Water will vary similarly. Vegetation will not vary temporally; but there is some inherent variation in vegetation spatially. Factors such as weather, trails, stock use, trampling, and stressors (e.g., contaminants, nonnative species, climate change, and phenology) are additional sources of variation. Edge effect could be significant, because edge may be the part of a meadow/wetland that changes first; edge effects will come from changes in soil and water.

4.8.6 Meadow and Wetland Plant Communities

Refer to Wetland Water Dynamics, above, for a description of our sampling design approach.

4.8.7 Macroinvertebrates (Meadows and Wetland)

Refer to Wetland Water Dynamics, above, for a description of our sampling design approach.

4.8.8 Landscape Mosaics

We will take the sampling approach of monitoring large scale landscape units on a longer temporal scale–some annually, others every five to ten years–primarily using nonrandom surveys (expert judgment) and remote sensing techniques. Spectral analysis will be applied when comparing imagery from time one and time two; those areas that are identified as having a significant spectral change will be investigated further. For example, fieldwork conducted through other protocols (such as Forest Dynamics) may be used to verify spectral changes identified in the analysis. A final step of the process would be to assign causality to the identified change, if possible.

In addition to an analysis of landscape change, it is desirable to perform analyses of the changes in the mosaics of landscape units. This will involve an analysis of the landscape patterns that characterize the composition, extent, and spatial arrangement of land cover and vegetation units.

We will want to focus a considerable amount of the effort on monitoring changes in metrics of forest/vegetation health over time, in conjunction with the change detection analysis (every five to ten years). Our sample design will be developed for applicability to other SIEN vital signs. These include monitoring fire regime, extent and health of meadows, detecting and monitoring invasions by non-native plants, and forest health and patch dynamics.

Much of the details of change detection methodology will be taken from NCCN vegetation monitoring protocols. The US Forest Service and California Department of Forestry and Fire Protection (CDF) have also instituted a change detection program for forests in the Sierra Nevada that is tailored to detecting changes to cover of conifer and hardwood forests over time (Fisher et al. 2004), but does not take a broader look at landscape mosaic patterns and dynamics. A sample design for landscape mosaics will be implemented to complement the USFS and CDF change detection program and to take advantage of their output.

4.8.9 Snowpack

Refer to Landscape Mosaics and Weather & Climate, above

4.8.10 Forest Dynamics

We are meeting with forest and fire ecologists (USGS and park staff) early in FY2007 to refine our monitoring objectives and determine our sampling approach.

4.8.11 Landbirds

We are meeting with bird biologists, park staff, and a statistician early in FY2007 to refine our monitoring objectives and determine our sampling approach.

4.8.12 Non-native Plants

Sample designs for non native plant monitoring will be geared towards early detection. We await publication of the NPS/USGS "Early Detection of Invasive Plant Species Handbook," anticipated in 2007.

In the meantime, SIEN is developing products necessary to fulfill development of early detection monitoring protocols and to conduct forthcoming Handbook recommendations: (1) periodic update of each park's non non-native plant species list; (2) a scheme for prioritization for early detection of specific species on SIEN park lists (above); (3) creation of a "watch list" of species not currently present in the parks but known to exist in the region or to have the potential to become problematic in the region; and (4) continued support for two monitoring projects already underway in SEKI and YOSE related to early detection of invasive plants in burned areas (these projects are being conducted by cooperators at University of Colorado and NASA Goddard Space Flight Center).

Table 4-1. **Proposed sampling design components for Sierra Nevada Network vital signs (scheduled for protocol development and implementation within the first five years of its monitoring program). Some vital signs with multiple objectives require different sampling strategies and membership design for different objectives.**

Vital Signs	Target Population	Membership Design	Revisit Design	Co-location or Co-visitation (integration) Opportunities
Water Chemistry	• SIEN lakes (lakes defined as greater 8 ha in area and 2 m deep) • SIEN streams (to be determined)	• Index sites • Extensive sites: Random, with spatial allocation (GRTS or similar)	To be determined	• Amphibians • Weather and Climate ? • Surface water dynamics
Surface Water Dynamics	• SIEN lakes (lakes defined as greater 8 ha in area and 2 m deep) • SIEN streams (to be determined)	To be determined	To be determined	• Landscape Mosaics (e.g., lake ice-out) • Water chemistry • Amphibians
Weather and Climate	• Existing monitoring sites (judgment sampling) • Others to be determined	To be determined	• Mostly continuous monitoring • Other to be determined	• Surface Water Dynamics ?
Wetland Water Dynamics	• All wetlands classified as wet meadows or fens	• Index sites • Extensive sites: Random, with spatial allocation (GRTS or similar)	To be determined	• Vegetattion (Meadow) Communities • Macroinvertebrates (Meadow)
Wetlands (Meadow) Ecological Integrity	• All wetlands classified as wet meadows or fens	• Index sites • Extensive sites: Random, with spatial allocation (GRTS or similar)	To be determined	• Macroinvertebrates • Wetland Water Dynamics
Selected Vegetation Communities (Meadows)	• All wetlands classified as wet meadows or fens	• Index sites • Extensive sites: Random, with spatial allocation (GRTS or similar)	To be determined	• Wetlands (Meadows) Ecological Integrity • Macroinvertebrates • Wetland Water Dynamics
Macroinvertebrates	• Species occurring in all wetlands classified as wet meadows or fens	• Index sites • Extensive sites: Random, with spatial allocation (GRTS or similar)	To be determined	• Vegetation Communities • Wetlands (Meadows) Ecological Integrity • Wetland Water Dynamics
Landscape mosaics	• SIEN parks, including buffer encompassing land outside park boundaries	• Census • Expert judgment • Other to be determined	Seasonal/Annual Every 5–12 years	• Surface Water Dynamics (ice-out) • Glaciers (snowfields)?
Forest dynamics	• To be determined–may include certain forest types (giant Sequoia, whitebark pine)	To be determined	To be determined	• Landscape mosaics?

Vital Signs	Target Population	Membership Design	Revisit Design	Co-location or Co-visitation (integration) Opportunities
Fire regimes	• SIEN parks	To be determined	To be determined	• Landscape mosaics
Amphibians	• SIEN lakes (lakes defined as greater 8 ha in area and 2 m deep)	• Index sites Extensive sites: Random, with spatial allocation (GRTS or similar)	To be determined	• Water chemistry
Landbirds	• SIEN parks	• Random, with spatial allocation (GRTS or similar)	• Rotating panel; revisit design to be determined	
Invasive / Exotic Plants	• SIEN "watchlist" species • High-value resource areas • Naturally-disturbed areas	• Not applicable	• Not applicable	• Vegetation Communities (Meadows)

Chapter 5 MONITORING PROTOCOLS

In order to produce high quality data and to detect long-term ecological trends, the Sierra Nevada Network will develop and maintain comprehensive monitoring (or 'sampling') protocols. Well-constructed, relevant, and accurate protocols help ensure that the trends we detect are the result of 'true' ecological change and not the result of how we measure or observe. They instill confidence in the Network monitoring program. They help us detect changes over time and with changes in personnel, and they allow us to compare data among places, parks, and agencies.

The NPS Inventory and Monitoring (I&M) Program and the USGS Status and Trends Program developed guidelines and adopted standards that all I&M funded protocols must adhere to (Oakley et al. 2003). Developing a sampling protocol that meets these standards requires a large upfront investment and well-defined objectives. Protocols should be fully documented with enough detail to ensure that consistent measurements will be taken throughout the monitoring period. Protocols should be able to withstand potential employee turnover and decades of technological change. In addition, all I&M funded protocols are peer-reviewed. (In the Pacific West Region, peer review is currently coordinated by Penny Latham, Regional I&M Coordinator, and Dr. James Agee, University of Washington.)

The Sierra Nevada Network is developing *eight protocols* over the next five years. This chapter outlines the Network's protocol development approach and provides an overview of specific protocols.

5.1 Approach to Protocol Development

To enable and energize protocol development, the Network assembled a suite of diverse work groups, with each group focusing on one or more vital signs. These work groups are comprised of Network, park, and local USGS staff with expertise in appropriate fields of study. Under the direction of the Network Coordinator and Science Committee, these workgroups

1. review, refine, and prioritize current monitoring objectives and mandates for each vital sign
2. review existing monitoring programs and protocols
3. refine pertinent conceptual models where appropriate
4. identify ways to integrate monitoring among/across vital signs
5. develop plans to fill data gaps
6. develop a general approach for monitoring and identify cooperators
7. ensure completion of protocols that meet I&M standards and network objectives by developing protocols in collaboration with cooperators or by overseeing protocol development agreements and contracts.

Nine work groups, each consisting of four to six people, were assembled in November 2005. These work groups focused on

1. amphibians
2. fire regimes
3. forest dynamics
4. landbirds
5. landscape
6. meadows
7. non-native plants
8. water
9. weather and climate

The collaborative efforts of the work groups led to the development and collation of vital signs to be used with specific protocols. The work groups, along with the Science Committee, determined that *eight protocols* should be developed to include the Network's *top 12 vital signs* (Table 5-1). Several protocols contain more than one vital sign, and some vital signs are captured by more than one protocol. The work groups will continue to be involved throughout protocol development.

Table 5-1. Relationship between protocols and vital signs.

Protocol	Vital Signs
Early Detection of Invasive Non-native Plants	non-native plants
Forest Dynamics	forest tree population dynamics
Lakes	surface water dynamics water chemistry amphibians
Landbirds	landbirds
Landscape Dynamics	landscape mosaics, fire regimes snowpack & glaciers
Meadow Ecological Integrity	wetland water dynamics meadow plant communities meadow invertebrates
Rivers and Streams	surface water dynamics water chemistry
Weather and Climate	weather and climate snowpack

5.2 Protocol Development Summaries

(This section is adapted from the Cumberland Piedmont Network's Vital Signs Monitoring Plan (Liebfreid et al. 2005).

The Network has developed protocol summaries (PDS) for all monitoring protocols that will be implemented in the next five years. These summaries describe why SIEN chose to develop each protocol and the protocol's monitoring objectives. Each PDS includes the following

1. **Protocol:** [title of the protocol]
2. **Parks Where Protocol will be Implemented:** [4-character codes for the parks where the protocol will be implemented over the next five years]
3. **Justification or Issues being Addressed:** [a brief summary justifying why this protocol is being developed]
4. **Specific Monitoring Questions and Objectives:** [as specific as possible]
5. **Basic Approach:** [description of any existing protocols or methods that will be incorporated into the protocol, the basic methodological approach and sampling design]
6. **Principal Investigators and NPS Lead:** [contact information for the Principal Investigators, including National Park Service staff and cooperators]
7. **Development Schedule, Budget, and Expected Interim Products:** [description of development costs, schedule with major milestones, and interim products]

The Sierra Nevada Network developed a PDS for each of the eight protocols. Summaries for earlier protocols are more detailed than those protocols that will be developed later. Work groups will fill in gaps as these protocols move forward. (*For more detailed information, please see Appendix K: Protocol Development Summaries.)*

5.3 Protocol Overviews

Protocols consist of three main sections or "modules": Narrative, Standard Operating Procedures (SOPs), and Supplemental Materials (Oakley et al. 2003). The Inventory and Monitoring program is taking this modular approach to better accommodate future revisions. It is easier to change and track revisions for a module (i.e., a narrative or SOP) than it is to modify a single large document.

5.3.1 The Protocol Narrative

The protocol *narrative* provides background information and an overview of the various aspects of the protocol that are addressed in more detail by the Standard Operating Procedures. It includes information on the resources being addressed, explains the rational for selecting and developing the protocol, and states the monitoring questions and measurable objectives. It describes the sampling design, including a justification for the selected design, criteria for site selection, description of the target population, sampling frequency, replication and timing, and number and location of sampling sites. The narrative also provides an overview of field and laboratory methods, data handling, analysis, and reporting. Personnel and operational requirements are outlined, including roles and responsibilities, workloads, schedules, facility and equipment needs, and budget information.

5.3.2 Standard Operating Procedures

The protocol details are found in the *Standard Operating Procedures*. These are a series of documents following the narrative that provide detailed instructions on how to carry out all aspects of the protocol. SOPs cover the entire monitoring process and at a minimum will include instructions for training, field season preparation, field methods, equipment operations, QA/QC procedures, database entry, data analysis, and delivery of information. Each SOP has a revision history log that is updated as changes are made.

5.3.3 Supporting Materials

The protocols point to *supporting materials* needed for monitoring and program management. These may include databases, reports, maps, geospatial data, custom software tools, and photographs.

5.4 Protocols

Each protocol will be a separate document; they will not be included in the Vital Signs Monitoring Plan. However, in the remainder of this chapter we provide a brief overview for each protocol the Sierra Nevada Network will be implementing in the next five years

5.4.1 Protocol: Early Detection of Non-Native Plants

Vital Signs: non-native plants

Justification: Invasive non-native plants can bring about significant changes in ecosystems by changing structural attributes of native plant communities (physiognomy, species composition, genetic diversity) and the processes that support them (fire, nutrient cycling, hydrology, soil erosion, decomposition). There are over 200 non-native plant taxa in Sierra Nevada Network parks, and new introductions continue to occur. Many of these taxa are invasive, or a threat to native plant and animal communities—they compete for space and resources, and often do not meet the same habitat needs of animals as do native plants. However, vast areas of the Network parks are free of invasive plants, and the highest invasive plant management priority for each of the parks is to prevent new introductions to these weed-free areas, to detect new introductions early in the invasion process, and to provide rapid eradication response. This protocol will provide parks with a systematic, efficient procedure for detecting new introductions.

Parks: DEPO, SEKI, YOSE

Monitoring Objectives:

1. Periodically review park weed management databases and update NPSpecies with new taxa not yet vouchered and documented. From NPSpecies, update each

park's non-native species list, using a defined set of criteria for inclusion, and evaluate changes.

2. Create and periodically update a "watch list" of species that are not present in the parks but are known to exist in the region or to have the potential to become problematic in the region.
3. Create and periodically update early detection monitoring priorities for species in the non-native and watch lists using a transparent, documented system.
4. Compile and periodically update polygons of weed-free areas, high-value resources areas, and naturally-disturbed areas, from a defined set of criteria, using existing information.
5. Within the polygons defined in Objective 4, detect (1) watch-list species and (2) new populations of priority species already present in the parks through either (a) complete search/census, or (b) sampling within search frames narrowed by selection criteria based on vectors, environmental factors, and other susceptibility measures.
6. Expand scope of personnel searching for watch-list species by developing SOPs and training materials to be included in other I&M protocols, in wilderness ranger duties, and in other park staff and volunteer efforts as appropriate.

5.4.2 Protocol: Forest Dynamics

Vital Signs: Forest tree population dynamics, lichen communities, or specific taxon *Bryoria fremontii* (which will be considered as an additional vital sign if feasible)

Justification: Forests occupy a significant portion of the vegetated area of Sierra Nevada parks, and giant sequoias are part of the enabling legislation for the parks' establishment. Forest tree population dynamics, or primarily, establishment, growth and death rates of trees are sensitive to changes in two major drivers in the Sierra Nevada: climate and fire. While there are other aspects of forest vegetation we will consider monitoring (e.g., lichen communities), we focus primarily on forest tree population dynamics because: 1) there is a successful track record of doing this kind of work already in these parks, and a wealth of baseline data exists; 2) forest tree population dynamics data are interpretable, and changes are often closely tied to drivers and/or stressors whose effects we seek to better understand (fire, climate, pollution and non-native species); and 3) trees comprise a keystone life form, creating the array of microclimates and habitats that entrain other ecosystem components and processes (such as wildlife and hydrology). Forests provide humans with irreplaceable resources and services; climatic change will profoundly affect forests; and forests may profoundly affect climatic change because they sequester the majority of the terrestrial biosphere's carbon, and they affect surface albedo and the hydrologic cycle.

Parks: SEKI, YOSE (DEPO to be included if species selected for monitoring occur in the monument)

Monitoring Objectives:

Giant sequoia, sugar pine, and whitebark pine were the species initially identified as highest priority.

1. Determine trends in populations of selected tree species (birth, growth, death rates). Add growth form to this list if monitoring whitebark pine.

2. Monitor trends in causes of tree death.

3. Monitor trends in white pine blister rust prevalence in five-needle pine populations.

Evaluate feasibility of adding this objective/vital sign:

4. Detect changes in the relative abundance of selected lichen taxa. [*Bryoria fremontii*, macrolichen communities in several vegetation types]

5.4.3 Protocol: Lakes

Vital Signs: Surface water dynamics, water chemistry, amphibians

Justification: Sierra Nevada Network parks protect over 4,500 lakes and ponds and thousands of kilometers of rivers and streams that have some of the highest water quality in the Sierra Nevada. High-elevation lakes are critical components of the parks' ecosystems, popular visitor destinations, and habitat for declining amphibian species. We will be monitoring three indicators at high-elevation lake ecosystems: water chemistry, hydrology, and amphibians. Hydrological and water chemistry measures are good indicators of aquatic and terrestrial ecosystem condition and trend because they reflect changes within the larger watershed. High-elevation lakes of the Sierra Nevada are especially sensitive to change because the waters are oligotrophic and have very low buffering capacities. It is well documented that amphibians are sensitive to ecosystem changes, are easy and relatively inexpensive to monitor, and measurements are highly repeatable. The main stressors that impact Sierra Nevada lake ecosystems include anthropogenic nitrogen deposition, pesticide deposition, climate change, non-native fish, visitor use, and pathogens (i.e., *chytridiomycosis*—an infectious disease that affects amphibians). Changes in nutrient cycles and shifts in phytoplankton communities in Sierra Nevada lakes have already been detected and attributed to increased nitrogen and phosphorous inputs (Goldman et al. 1993, Sickman et al. 2003).). Mountain yellow-legged frog (*Rana muscosa)* and Yosemite toad (*Bufo canorus*) populations are rapidly declining—they are candidates for listing as 'endangered'. Change detected in high-elevation lakes can be an early warning indication of change that may eventually occur at other elevations and ecosystem types.

Parks: SEKI, YOSE

Monitoring Objectives:

Survey Sites:

1. Detect long-term trends in lake water chemistry for Sierra Nevada Network lakes.
   - Temp, pH, sp. conductance, dissolved oxygen, acid neutralizing capacity
   - Major ions: Ca, Na, Mg, K, Cl, SO4
   - Nitrate, dissolved organic nitrogen, total dissolved nitrogen
   - Total dissolved phosphorus
   - Particulate nitrogen, particulate phosphorus, particulate carbon
2. Characterize Sierra Nevada Network lakes.
3. Determine the proportion of Sierra Nevada Network lakes above threshold values for selected constituents.
4. Detect long-term trends and abundance of high-elevation anurans, particularly mountain yellow-legged frog, Yosemite toad, and Pacific tree frog for Sierra Nevada Network lakes.

Index Sites:

1. Detect intra- and inter-annual trends in lake water chemistry for Sierra Nevada Network index lakes.
   - Temp, pH, sp. conductance, dissolved oxygen, acid neutralizing capacity
   - Major ions: Ca, Na, Mg, K, Cl, SO4
   - Nitrate, dissolved organic nitrogen, total dissolved nitrogen
   - Particulate nitrogen, phosphorus, carbon
   - Total dissolved phosphorus
2. Detect intra- and inter-annual trends in lake level and outflow for Sierra Nevada Network index sites.
3. Detect inter-annual trends and abundance of high-elevation anurans, particularly Mountain yellow-legged frog, Yosemite toad, and Pacific tree frog for Sierra Nevada Network index sites.

5.4.4 Protocol: Landbirds

Vital Signs: Landbirds

Justification: Increasingly, birds are perceived as appropriate indicator species of local and regional change in terrestrial ecosystems. Sierra Nevada Network parks together provide over 1,600,000 acres of habitat for over 200 species of birds, including many neotropical migrants. SEKI, YOSE and a few other large habitat areas in the Sierra Nevada have been designated by the American Bird Conservancy as Globally Important Bird Areas (IBA). The aim of the IBA Program is to identify and conserve key sites for birds. Analysis of North American Breeding Bird Survey data indicates that numerous bird species exhibit declining long-term population trends in the Sierra Nevada region (DeSante 1995, Graber 1996).

Parks: DEPO, SEKI, YOSE

Monitoring Objectives:

The landbird workgroup will be meeting during Spring 2007 to refine its monitoring objectives and review funding alternatives.

1. Determine status or trends in abundance (density) and frequency of occurrence in birds in SIEN parks during the breeding season.
   - Make park-level inference on changes in density and frequency of occurrence of widely distributed species in the Sierra Nevada to describe SIEN patterns, variation, and differences between parks.

If funding for landbirds is limited due to other vital sign priorities, the Network may instead:

2. Make SIEN-level inference in density and frequency of occurrence for subalpine, riparian, wetland, and other habitat-specialist species.

5.4.5 Protocol: Landscape Dynamics

Vital Signs: landscape mosaics, fire regimes, snowpack, glaciers

Justification: Regional science has identified habitat fragmentation, invasive species, altered fire regimes, pollution, and climate change as the five primary threats to Sierra Nevada systems. The parks of the Sierra Nevada Network help to protect one of the nation's and the world's most biotically unique and diverse locations; the region is identified as a global biodiversity hotspot. In accordance with this recognition, resource managers of the Sierra Nevada Network parks must document and assess landscape changes. To assess change, the landscape components and dynamics to be monitored will include land use, vegetated land cover mosaic and condition, fire occurrence, snow cover extent and duration, and extent of glaciers and permanent snow fields. Fire regimes and climate are the most important ecosystem drivers in the Sierra Nevada. While monitoring of climate is a separate protocol, we have included monitoring fire regimes in the landscape dynamics protocol due to the direct effects of fire on plant community composition and structure. Fire regime characteristics (such as size, frequency, and severity) are sensitive to changes in climate regime and will influence vegetation pattern (including patch and gap dynamics).

Remote sensing of land use patterns offers a relatively rapid and cost effective method to assess large and small spatial scale changes in the landscape. There are two primary justifications for wanting to monitor the change in landscape dynamics or mosaics over time. One is to document the change where and when it occurs, informing response to crises or directing managers to areas of heightened concern. Collected data and analysis will allow for the preparation of scientific responses to environmental change. The second is to use data to build models of predicted future landscape mosaic patterns, allowing managers to better prepare for and then manage for ecosystem changes that are likely to affect processes, systems, and individual species.

Parks: DEPO, SEKI, YOSE

Monitoring Objectives:

The objectives are to answer the following questions

1. How is land cover and land use changing over time? Describe landscape pattern (status and trends) in and outside park of the mosaic (extent, size distribution, etc). Include both vegetation and abiotic land cover (snow and rock).
2. How are the landscape units changing in distribution and abundance over time? Monitor the status and trends of landscape composition (abitoic and vegetation types) in space and time (richness, evenness, etc).
3. How is the condition of plant communities or vegetation alliances changing in space and time? Monitor vegetation condition using several remotely sensed metrics (NDVI, LAI, FPAR).
4. Monitor fire occurrence (location and spatial extent), severity, and fire type annually, and the temporal nature of fire events (including ignition and area burned seasonally) intra-annually. This will provide information to determine trends in fire return interval and fire size.
5. How is the spatial extent and duration of snow cover changing over time?
6. How is vegetation phenology changing over time? Monitor changes in the timing of leafout and duration of growing season.

5.4.6 Protocol: Meadow Ecological Integrity

Vital Signs: Wetland water dynamics, meadow plant communities, meadow invertebrates

Justification: Meadow wetlands are of ecological importance disproportionate to their size. They are areas of high net productivity, high species diversity, and serve important physical and chemical functions such as nutrient uptake, sediment trapping, and habitat for wildlife. Meadows produce food for wildlife both within the meadows and adjacent upland areas. Meadows are important to park visitors for their wildlife, wildflower displays, overall aesthetic qualities, and as forage for recreational pack stock. Meadows are fragile and may be impacted from many different stressors that include grazing (contemporary from pack stock and alterations caused by historic grazing practices with cattle and sheep), invasive plants and animals, trampling (human and stock), atmospheric nutrient deposition, agricultural contaminant deposition, global warming, disturbance (human and stock), habitat fragmentation from trails, altered hydrology from trails and roads, non-native diseases, and loss of sediment due to altered fire regime in adjacent upland areas. Meadows were selected for monitoring because of their ecological significance, fragility, and because they are represented well across the Sierra Network landscape in montane, subalpine, and alpine areas and in all sizes from small to large. National Wetland Inventory maps show that over 14,000 meadow wetlands occur within the Network.

Park: DEPO, SEKI, YOSE

Monitoring Objectives:

1. Determine temporal changes in species composition and abundance of meadow vascular and non-vascular flora, including changes in exposed bare ground.
2. Determine temporal changes in the composition and relative abundance of above-ground meadow invertebrate populations at the level of Family (Order when necessary for efficiency) except for identifying ants to species.
3. Determine temporal changes in hydrology including the duration, depth, and timing of surface and ground water.
4. Document temporal changes in wet meadow geomorphic process to include sediment flux into meadows and meadow soil density for sentinel sites and morphology and condition of meadow streams at all sites.
5. Document temporal changes in electrical conductivity and water temperature of meadow water.
6. Document temporal changes in coarse measures of anthropogenic influences to meadows.

For each of the objectives, the protocols will be designed to detect at least a 20 percent decadal change with 80 percent power.

5.4.7 Protocol: Rivers and Streams

Vital Signs: Surface water dynamics, water chemistry

Justification: Sierra Nevada Network parks protect over 4,500 lakes and ponds and thousands of kilometers of rivers and streams that have some of the highest water quality in the Sierra Nevada. Water resources are critical components of the parks' ecosystems and popular visitor recreation and camping destinations. Hydrological and water chemistry measures are good indicators of aquatic and terrestrial ecosystem condition and trends because they reflect changes within the larger watershed. The stressors of greatest concern to the parks' flow regimes and water quality are climate change, altered fire regimes, air pollution (i.e. nitrogen and pesticide deposition), and local impacts from visitor use and park operations.

Park: DEPO, SEKI, YOSE

Monitoring Objectives:

The Network will identify specific monitoring objectives in fall of 2007 when the Rivers and Streams protocol development begins.

5.4.8 Protocol: Weather and Climate

Vital Signs: Weather and climate, snowpack

Justification: Climatic forces are a major driver of Sierra Nevada ecosystems. Current patterns of vegetation, water dynamics, and animal distribution in the Sierra are determined largely by cumulative effects of past and present climates. Not surprisingly, anthropogenic climate change is the stressor that is predicted to have the most pronounced effects on Sierra Nevada ecosystems. Changes attributed to climate change have already been observed in Sierra Nevada---peak spring stream flows begin a week to almost three weeks earlier than they did in the mid 20th century (Cayan et al. 2001, Dettinger 2005) and glacial extent has declined markedly in the past several decades (Basagic in progress). A recent resurvey of vertebrate transects in Yosemite that were originally surveyed in 1911-1920 suggests that a warming climate may be affecting animal distributions. Elevational shifts were observed in ground squirrels, alpine chipmunks, and pika (Patton 2006). Weather and climate monitoring information will enable managers to better track climate change in Sierra Nevada parks and its effects on park resources. Weather and climate information will also enable us to better explain trends observed in other vital signs.

Park: DEPO, SEQU, KICA, and YOSE

Monitoring Objectives:

The Network will identify specific monitoring objectives in fall 2007 upon completion of a Climate Monitoring Assessment project the Network established with the Western Regional Climate through the Great Basin CESU. The purpose of this project is to assess the current climate monitoring Network in Sierra Nevada parks, provide the necessary analyses, and make recommendations on how the Sierra Nevada Network can best allocate its resources to enhance weather and climate monitoring.

Chapter 6 DATA MANAGEMENT

Collecting data on natural resources is the first step toward understanding ecosystems within national parks. These “raw” data are used to analyze, synthesize, and model aspects of ecosystem components and processes. In turn, results and interpretations are used to make decisions concerning park resources. Thus, *data* collected and maintained by the Sierra Nevada Network (SIEN) will become *information* for decision-making through analysis, synthesis, and modeling.

Data management encompass the attitudes, habits, procedures, standards, and infrastructure related to the acquisition, maintenance, and disposition of data and its resulting information. Data management is not an end unto itself but, instead, a means of maximizing quality and utility of natural resource information.

This chapter summarizes the SIEN data management strategy which is more fully addressed in the SIEN Data Management Plan (DMP: (Cook and Lineback 2006). The DMP describes an overarching strategy for ensuring that program data are controlled for quality, well documented and secure, and remain accessible and useful for decades into the future. In turn, the DMP refers to more specific guidance documents and standard operating procedures applicable to individual vital signs monitoring protocols. The intended audience includes: the SIEN I&M Program; Network park natural resource management programs; USGS field stations located in YOSE and SEKI; and cooperators who have either a fiscal or formal agreement relationship with these programs.

6.1 Goals and Objectives of Data Management

As part of the NPS effort to “improve park management through greater reliance on scientific knowledge,” a primary purpose of the Inventory and Monitoring (I&M) Program is to develop, organize, and make available natural resource data and information to contribute to the Service’s institutional knowledge.

In this context, “information” encompasses other types of products generated along with primary tabular and spatial data, such as metadata, maps, statistical models, diagrams, and reports. Meeting program goals for Vital Signs monitoring data and information requires the development of an integrated management system involving many components (Figure 6-1).

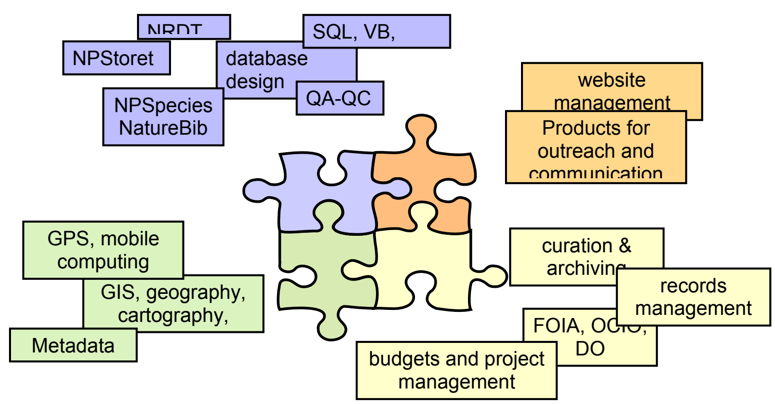


Figure 6-1: Vast array of data management puzzle pieces.

The goal of SIEN data management is to ensure the quality, interpretability, security, longevity and availability of ecological data and related information resulting from natural resource inventory and monitoring efforts. These fundamental concepts are defined as follows

- *Quality* – Awareness of the quality of information and its underlying data is fundamental to its proper use. Our objective is to ensure that appropriate quality assurance measures are taken during all phases of project development, data acquisition, data handling, summary and analysis, reporting, and archiving. These measures reflect current best practices and meet rigorous scientific standards.

- *Interpretability* – A data set is only useful if readily understood and appropriately interpreted in the context of its original scope and intent. Data taken out of context can lead to misinterpretation and misunderstanding. Our objective is to ensure that sufficient documentation accompanies each data set, and any reports and summaries derived from it, so users will be aware of its context, applicability, and limitations.

- *Security* – Our objective is to make certain that both digital and analog forms of source data are maintained and archived in an environment that provides appropriate levels of access to project managers, technicians, decision makers, and others.

- *Longevity* – Countless data sets have been lost over time simply due to insufficient documentation and organization. Our objective is to ensure that data sets are maintained in an accessible and interpretable format, and accompanied by sufficient documentation. Although this requires an initial investment of time and effort, this investment almost certainly pays off over time because the data set is much more likely to be used.

- *Availability* – Natural resource information can only be useful for informing decisions if it is available to managers at the appropriate time and in a usable form. Our objective is to expand the availability of natural resource information by ensuring that products of inventory and monitoring efforts are created, documented, and maintained in a manner that is transparent to the potential users of these products.

6.2 Systems Infrastructure and Architecture

A modern data management infrastructure (e.g., staffing, hardware, software) represents the foundation upon which our network information system is built. *Infrastructure* refers to the system of computers and servers that are functionally or directly linked through computer networking services. *Architecture* refers to the applications, database systems, repositories, and software tools that make up the framework of an information management system. The SIEN relies on park, network, and national Information Technology (IT) personnel and resources to maintain a computer systems infrastructure and architecture. This includes but is not limited to hardware replacement, software updates and support, security updates, virus-protection, telecommunications networking, and server backups. Therefore communication with park and national personnel is essential to ensure adequate resources and service continuity.

An important element of an information management program is a reliable, secure network of computers and servers. Our digital infrastructure has three main components: a network-based local area network (LAN), a regional wide-area network (WAN), and servers maintained at the national level (Figure 6-2). Each of these components hosts different parts of our natural resource information system.

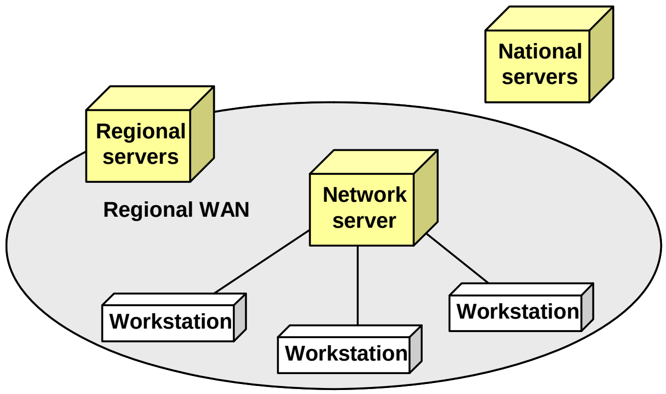


Figure 6-2. Main components of the Sierra Nevada Network.

IT duties for Network programs such as I&M are provided by the IT staff at SEKI and YOSE. These include hosting and managing Network electronic files being created, managed, and disseminated by Network staff and cooperators. SEKI staff provide IT support to Devils Postpile. The SEKI LAN will be the primary repository for I&M electronic files with access available to YOSE and DEPO staff and I&M employees working in these parks. Files will be managed within a standardized electronic directory structure organized by project. Long term plans for the Network include a content management system. It is anticipated that YOSE IT staff will provide additional, specialized support as Network parks begin implementing the Network's DMP, such as Citrix administration that will enable park employees to utilize ArcGIS software across wide area networks with low bandwidth connections. Security will be achieved through electronic file and directory permissions with administration rights controlled by IT personnel and a limited number of trained program staff.

Data management support from the Washington office includes hosting and maintaining several databases on national servers. These online databases will be used for summarizing park-level data at the national level, providing a means for storing and making accessible basic natural resource data and information for the parks. Sensitive data and information is prevented from public release through the implementation of a dual system of secure and public servers. Applications include

- *NatureBib* – the master database for natural resource bibliographic references
- *NPSpecies* – a database application that lists the species that occur in or near each park, and the physical or written evidence for the occurrence of the species (i.e., references, vouchers, and observations)

- *Biodiversity Data Store* – a digital repository of documents, GIS and other data sets that contribute to the knowledge of biodiversity in National Park units, including presense/absence, distribution and abundance
- *NPS Data Store* – a centralized repository and graphical search interface that links data set metadata to a searchable data server on which data sets are organized by NPS units, offices, and programs.

The Biodiversity and NPS Data Stores contain sensitive data and information and access is available only through prior authorization. Unrestricted public outlets for digital data products include

- *NPSFocus* – a decentralized digital image/resource management application that offers one-stop searching and browsing for digital imagery (pictorial, drawings, maps, texts, and GIS DOQ/DRG images) and metadata from separate image collections maintained by parks and NPS programs.
- *NPS GIS Clearinghouse* – a public repository of GIS products produced by the NPS, including a link to the NPS Data Store and the NPS Interactive Map Center which delivers base maps and park brochure maps for geographic reference and navigation. Non-sensitive GIS data uploaded to the NPS Data Store are automatically posted to this site.

Water quality monitoring data collected in and around national park units are disseminated through STORET (STORage and RETrieval), an interagency database developed and supported by the Environmental Protection Agency to house local, state, and federal water quality data collected in support of managing the nation's water resources under the Clean Water Act.

At the local level, park resources for data management include

- ArcGIS for managing spatial data and metadata
- NPS Metadata Tools and Editor for editing and transferring metadata to the *NPS Data Store*
- Microsoft Access for developing project databases
- Microsoft Sharepoint Services, currently hosted by the PWR office
- Lotus Sametime Meeting for Internet and video conferencing

6.3 Project Workflow

From the perspective of managing work flow, there are two main types of projects

- s*hort-term*, which may include individual park research projects, inventories, or pilot work in preparation for long-term monitoring,

- *long-term*, which are mainly implemented monitoring projects central to the I&M program, but may also include multi-year research projects and monitoring performed by other agencies and cooperators. Long-term projects often require a higher level of documentation, peer review, and program support.

With respect to data management, a primary difference between short- and long-term projects is an increased need to adhere to standards for the latter to ensure internal compatibility over time.

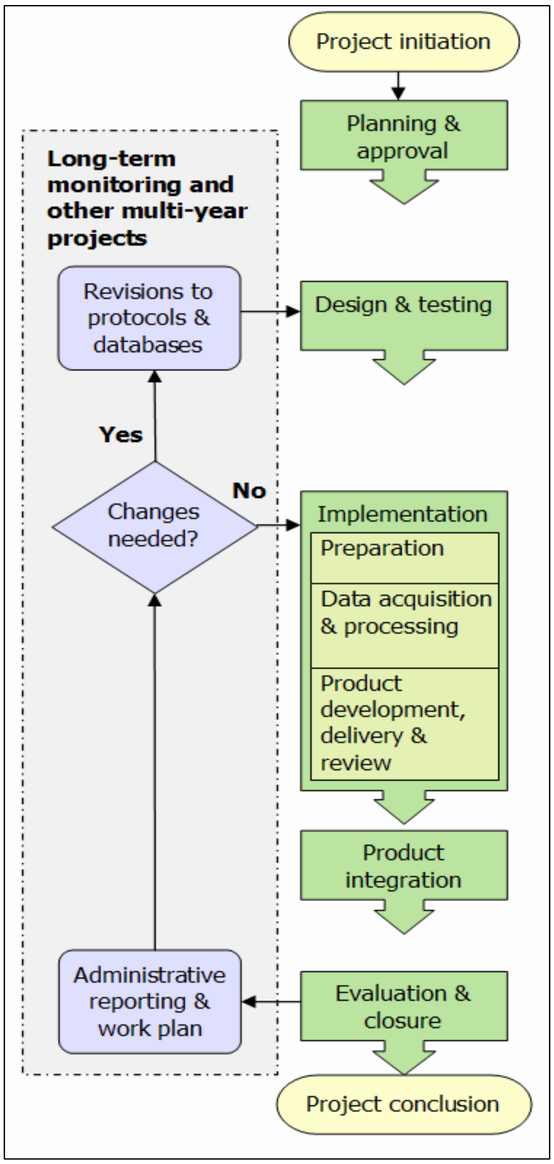


Figure 6-3. Primary Projects Stages.

Projects can be divided into five primary stages (Figure 6-3), each characterized by a set of activities carried out by involved staff.

- *Planning and approval* – Many preliminary decisions are made regarding project scope and objectives. Funding sources, permits, and compliance are also addressed at this stage.

- *Design and testing* – Details regarding how data will be acquired, processed, analyzed, documented, reported and made available to others are worked out. Development of the data design and data dictionary is initiated, and specifics of protocol implementation and collected data parameters are defined in detail.

- *Implementation* – Data are acquired, processed, error-checked, and documented. Products such as reports, maps, GIS themes are developed and delivered. Data management staff function primarily as facilitators, providing training and support for: database applications, GIS, GPS and other data processing applications; facilitation of data summarization, validation and analysis; and assistance with the technical aspects of documentation and product development.

- *Product integration* – Data products and other deliverables are integrated into national and network databases, metadata records are finalized and posted in clearinghouses, and products are distributed or otherwise made available to their intended audience. Data from working databases are uploaded to the master database maintained on network servers.

- *Evaluation and closure* – Status of projects and their deliverables are updated in a network project tracking application. Program administrators, project leaders, and data managers assess how well projects have met their objectives.

Throughout the workflow of a project, data take different forms and are maintained in different places as they are acquired, processed, documented, and archived.

Key points of the data life cycle are as follows

- All raw data are archived intact.
- Working databases are the focal point of all modification, processing, and documentation of data collected for a given time period.
- Upon certification, whereby all documentation and quality assurance requirements are satisfied, data are archived and posted or otherwise integrated with national applications and repositories.
- For long-term monitoring projects, data are uploaded into a master database that includes multiple years of data.
- Certified data sets are used to develop reports and other data products (maps, checklists, etc.). These products are also archived and posted to appropriate national applications and repositories.
- All subsequent changes to certified data sets are documented in an edit log, which is distributed with the data.

6.4 Information Stewardship Roles and Responsibilities

Nearly everyone in an organization manages data and information at some level. Good data stewardship is truly a collaborative endeavor that involves many people with a broad range of tasks and responsibilities. As such, a valid data management system must be developed and continually modified to meet the needs of everyone who has a role in coordinating, generating, maintaining, and using natural resource information in its many forms. For the I&M Program, this will constitute a diverse group of employees made up of park managers and scientists, data managers, GIS staff, IT specialists, project managers and technicians, and interpreters (Table 6-1).

Table 6-1. I&M roles and responsibilities for data stewardship.

Role	Data Stewardship Responsibilities
Network Coordinator	Ensures programmatic requirements are met as part of overall Network business.
Network Data Manager	Ensures inventory and monitoring data are organized, useful, compliant, secure, and available.
Project Leader	Directs project operations. Communicates information management requirements and protocols to project staff, Network Data Manager, and resource specialist(s). Responsible for final submission and review of all products and deliverables.
Project Crew Leader	Supervises crew and ensures adherence to data collection and processing protocols, including data verification and documentation.
Project Crew Member	Collects, records and verifies measurements based on project objectives and protocols. Documents methods and procedures.
Data/GIS Technician	Processes and manages data.
Statistician/Biometrician/ Quantitative Ecologist	Analyzes data, consults on analyses, and document procedures.
Network Ecologist/Physical Scientist	Ensures useful data are collected and managed by integrating natural resource science into Network activities and products.
Park Resource Specialist	Understands project objectives, data, and management relevance. Makes decisions about validity, sensitivity, and availability of data.
Curator (Park or Region)	Manages collection, documentation, and preservation of specimens.
GIS Manager (Region)	Provides GIS support including long-term storage of data, updated software, and technical assistance.
Information Technology Specialist (Network or Region)	Provides IT support for hardware, software, and network.
I&M Data Manager (National)	Provides Service-wide database availability and support
End Users (managers, scientists, Interpreters, public)	Informs the scope and direction of science information needs and activities. Interprets information and applies to decisions.

6.5 Database Design

The SIEN strategy for managing project data relies upon standalone MS Access databases that share design standards, established by the Natural Resources Database Template (http://science.nature.nps.gov/im/apps/template/index.cfm), and links to centralized data tables for maintaining consistency in shared information (e.g., geographic place names, species taxonomic nomenclature). Individual project databases are developed, maintained, and archived separately. Advantages to this strategy include

- Data sets that are modular, allowing greater flexibility in accommodating the needs of each project area.
- Individual project databases and protocols can be developed at different rates without a significant cost to data integration.
- Any project database can be modified without affecting the functionality of other project databases.

- Large initial investment in a centralized database and the concomitant difficulties of integrating among project areas with very different, and often unforeseen, structural requirements can be avoided.
- Potentially greater efficiency for interdisciplinary use.

6.6 Data Acquisition and Processing

Large, multi-scale natural resources programs, such as Vital Signs Monitoring, increasingly rely on data and information gathered from multiple sources. The SIEN DMP describes the general steps involved with acquiring, processing, and reporting data gathered as part of vital signs monitoring, along with legacy data gathered both from within and outside of the NPS, to meet standards established by the NPS I&M Program for quality, documentation, and preservation. Also included are guidelines for the acquisition and processing of physical objects (photographs, voucher specimens) which are often collected as part of resource management, inventory and monitoring, and other research projects. Instructions specific to particular projects will be developed and included with the protocols for those projects.

6.7 Quality Assurance and Quality Control

The success of the I&M Program will ultimately depend on the quality of the data that are collected, processed, and disseminated. To ensure data of the highest quality, procedures have been established to identify and minimize errors at each project stage associated with the data life cycle. Quality assurance and quality control protocols and execution are joint responsibilities, the results of which are documented to notify end users of the level of data quality.

Although some quality control procedures depend upon the nature of a specific project, some general concepts apply to all network projects. To ensure that all SIEN vital signs monitoring projects produce and maintain data of the highest quality, a common set of procedures has been developed to identify and minimize both the frequency and significance of error at all stages in the data life cycle (Figure 6-4).

Examples of quality assurance practices include

- Field crew training
- Standardized field data forms with descriptive data dictionaries
- Use of handheld computers and data loggers with built-in controls
- Equipment maintenance and calibration
- Procedures for handling data in the field
- Database features to minimize transcription errors, including range limits, pick lists, etc.

Verification and validation, including automated error-checking database routines and quality assurance methods should be in place at the inception of any project and continue through all project stages to final archiving of the data set.

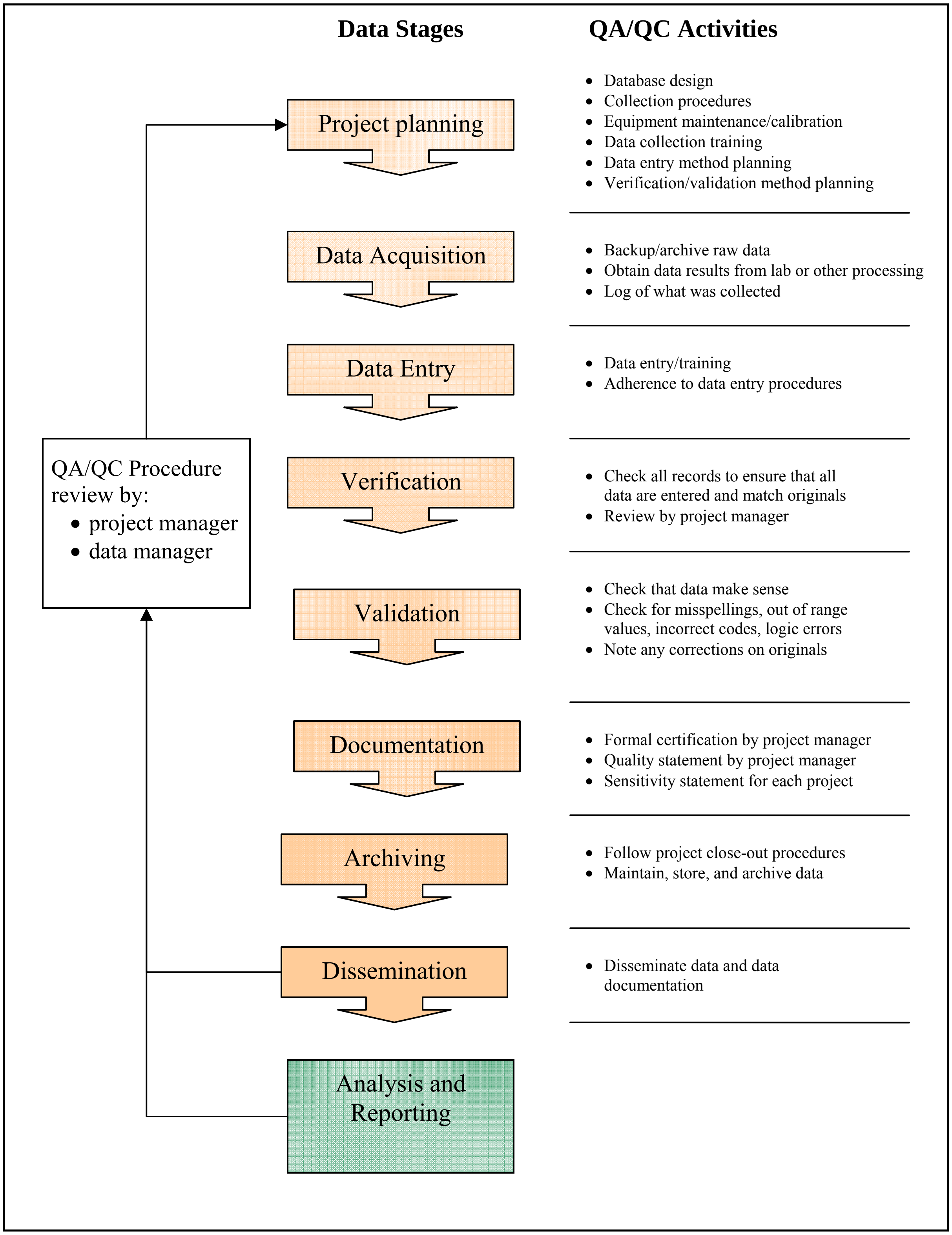


Figure 6-4. General course of data and associated Quality Assurance/Quality Control procedures.

As a final step, a statement of data quality will be composed by the Project Leader and incorporated into the formal metadata, which will include information on the specific quality assurance procedures applied and the results of the review.

6.8 Data Documentation

Documentation is essential to the longevity and value of project data. Anyone using these data in the future will need to know as much as possible about what, where, how, when, why, and by whom the data were collected, along with appropriate uses, including restrictions on sensitive information, and any known limitations. A good data management system cannot simply attend to the tables, fields, and values that comprise a data set. It also must provide a process for developing, preserving, and integrating the research context that makes data interpretable and useful. For the SIEN, this will involve the development of formal metadata—a detailed, structured set of information about the content, quality, condition, and other characteristics of project data.

The development of formal metadata which will following Federal Geographic Data Committee and NPS standards for content and format will also enable the cataloging of project data sets within intranet and internet systems, thereby making them available to a broad range of potential users.

Metadata for all SIEN monitoring projects will be parsed into two nested levels of detail, each with a specific audience in mind. Level 1, or "Manager Level" will present an overview of the product crafted to quickly convey the essentials needed to understand the context of the data. Level 2, or "Full Metadata" will contain all components of supporting information such that the data may be confidently manipulated, analyzed and synthesized.

There are a variety of software tools available for creating and maintaining metadata. The SIEN will use one or more of the following

- ESRI's ArcCatalog
- NPS Metadata Tools and Editor
- The "Metadata in Plain Language" questionnaire

SIEN data management staff will provide training and support in the use of these tools to project leaders and will aid in metadata development where practical. Upon completion, metadata will be posted with project data so that they area available and searchable along with their constituent data sets data and reports via the SIEN Internet web site and the NPS Data Store.

6.9 Data Ownership and Sharing

SIEN data and information products are considered property of the NPS. However the Freedom of Information Act (FOIA) establishes access by any person to federal agency records that are not protected from disclosure by any exemption or by special law enforcement record exclusions. We will comply with all FOIA strictures regarding sensitive data. If the NPS determines that disclosure of information would be harmful, information may be withheld concerning the nature and specific location of

- Endangered, threatened, rare or commercially valuable National Park System Resources (species and habitats)
- Mineral or paleontological objects
- Objects of cultural patrimony
- Significant caves

Each project leader, as the primary data steward, will determine data sensitivity in light of federal law, and will stipulate the conditions for release of the data in the project protocol and metadata. Network staff will classify sensitive data on a case by case, project by project, basis. They will work closely with investigators for each project to ensure that potentially sensitive park resources are identified, and that information about these resources is tracked throughout the project.

Network staff are also responsible for identifying all potentially sensitive resources to principal investigator(s) working on each project. Investigators, whether network employees or partners, will develop procedures to flag all potentially sensitive resources in any products that come from the project, including documents, maps, databases, and metadata. When submitting any products or results, investigators should specifically identify all records and other references to potentially sensitive resources. Partners should not release any information in a public forum before consulting with Network staff to ensure that the information is not classified as sensitive or protected.

The following guidance for determining whether information should be protected is suggested in the draft Director's Order #66 (the final guidance will be contained in Reference Manual 66)

- Has harm, theft, or destruction occurred to a similar resource on federal, state, or private lands?
- Has harm, theft, or destruction occurred to other types of resources of similar commercial value, cultural importance, rarity, or threatened or endangered status on federal, state, or private lands?
- Is information about locations of the park resource in the park specific enough so that the park resource is likely to be found at these locations at predictable times now or in the future?
- Would information about the nature of the park resource that is otherwise not of concern permit determining locations of the resource if the information were available in conjunction with other specific types or classes of information?
- Even where relatively out-dated, is there information that would reveal locations or characteristics of the park resource such that the information could be used to find the park resource as it exists now or is likely to exist in the future?
- Does NPS have the capacity to protect the park resource if the public knows its specific location?

Natural Resource information that is sensitive or protected requires the following steps

- Identification of potentially sensitive resources.

- Compilation of all records relating to those resources.
- Determination of what data must not be released to the public.
- Management and archival of those records to avoid their unintentional release.

6.10 Data Dissemination

Public access to SIEN data and information products will be facilitated through a variety of information systems that allow users to browse, search and acquire I&M project data and supporting documents. These systems include the SIEN I&M data server, digital library, and website, and national applications with internet interfaces (Table 6-2).

Table 6-2. Public-access repositories for SIEN data and information.

ITEM	REPOSITORY
Reports (public) digital	SIEN network servers, SIEN public website, NPS Data Store, NPSFocus
hard copy	SIEN I&M library, YOSE Library, USGS libraries
bibliography	NatureBib
Network-generated digital datasets and data products (public, non-sensitive) • Certified data and data products (including photographs) • Metadata	SIEN network servers, NPS Data Store, Biodiversity Data Store, NPSpecies, NPS GIS Clearinghouse, EPA STORET

Network products also will be available via data requests fulfilled using either electronic file transfer protocol (FTP), email attachments for small file sizes, or shipment of digital media such as DVDs or CD-ROMs.

Water quality data collected to meet federal regulatory requirements are managed according to guidelines from the NPS Water Resources Division (WRD), which also oversees the integrated water quality monitoring portion of the I&M Program. WRD requirements stipulate the use of the NPSTORET desktop database application by I&M networks to help manage data entry, documentation, and transfer. Data from NPSTORET are transferred periodically to the Environmental Protection Agency's STORET National Data Warehouse (Figure 6-5). Individual networks are free to use NPSTORET for data entry and maintenance, or to develop a customized database compatible for data exchange and delivery. The SIEN may choose the latter and build a desktop application that would also interface with the State of California's Environmental Data Exchange Network (CEDEN). Data would then be provided to WRD for upload to STORET on an annual basis in accordance with NPS STORET Electronic Data Deliverable file specifications.

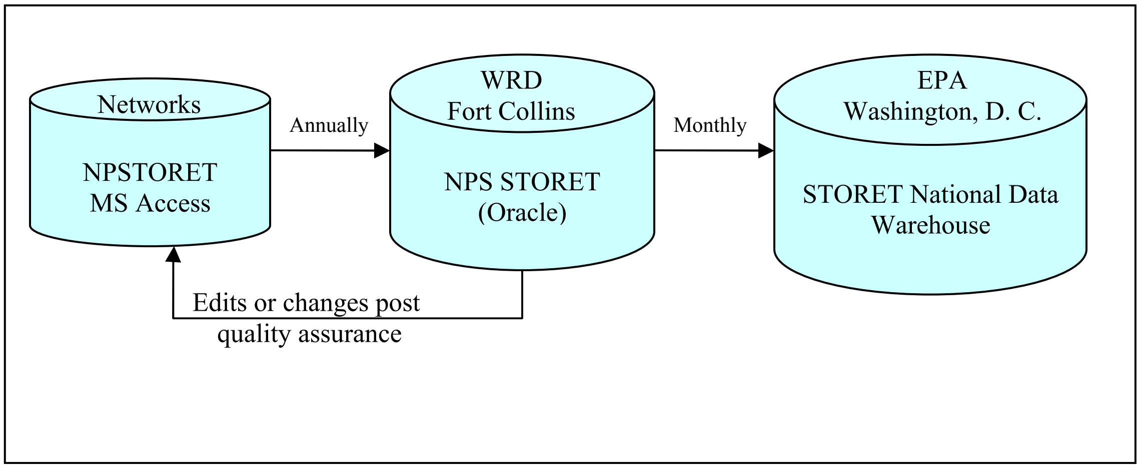


Figure 6-5. Flow diagram for water quality data from I&M networks to the National Data Warehouse.

6.11 Records Management and Object Storage

Data maintenance, storage and archiving procedures will ensure that data and related documents and associated physical objects are

- Kept up-to-date with regards to content and format such that the data are easily accessed and their heritage and quality easily learned
- Physically secure against environmental hazards, catastrophe, and human malice

Technological obsolescence is a significant cause of information loss, and data can quickly become inaccessible to users if they are stored in out-of-date software programs or on outmoded media. Effective maintenance of digital files depends on the proper management of a continuously changing infrastructure of hardware, software, file formats, and storage media. Major changes in hardware can be expected every one to two years and in software every one to five years. As software and hardware evolve, data sets must be consistently migrated to new platforms, or they must be saved in formats that are independent of specific platforms or software (e.g., ASCII delimited files). Data maintenance schedules will be developed to ensure that data are migrated and kept up-to-date.

6.12 Implementation

The data management plans for each of the 32 I&M Networks are the first comprehensive documents of their kind in the NPS and contain practices that may be new to staff and cooperators. However, almost every requirement stems from federal law, Executive Orders, Director's Orders, or national I&M Program guidance. The DMP helps put these requirements into context, and provides operational guidance for achieving them.

The main body of the plan broadly addresses relevant subjects, but directs most of the details into individual appendices that serve as stand-alone documents for ease of locating and retrieving specific information of greatest value to most users. The next plan revision should be completed within three years or by October 1, 2010, and then every five years afterward. Plan appendices, including SOPs, detailed guidelines, reference manuals, policy statements, etc., will likely require more frequent updates to account e.g., for changes in technology or availability of better information.

Implementation will require education and training in order to familiarize park staff and cooperators with the tools, procedures, and guidelines outlined in the plan. These efforts will begin in 2007 and be led, at least initially, by I&M data management staff and the SEKI GIS coordinator, with additional technical staff from all parks encouraged to participate. Full implementation will require the assistance of IT and curatorial staff at SEKI and YOSE as well. Goals for the first 3 years should include

- All staff of targeted programs and their cooperators understand the fundamentals of data and information management, including
  - File management
  - Documentation
  - Quality assurance and quality control
  - Electronic storage
  - Archive storage
- Data management practices are improved by implementing
  - Accepted database design standards
  - Thorough testing of databases, data collection methods, and their integration prior to field work
  - Quality assurance and control procedures at every stage of project development
- Common SOPs and guidance documents for multiple protocols
- Detailed specifications for data management consistent with the DMP are included in every vital signs monitoring protocol
- Procedures and outlets for communication within and among Network parks and with the public

Beyond the first three years, goals should include the development and assessment of

- Procedures to facilitate the summarization and reporting of monitoring data
- Framework and gateway for integration of monitoring data with other agencies or networks
- Methods for improving file management (e.g., a content management system), database administration and security (e.g., migration to SQL-Server), integration into the network of off-site users, and other needs identified in the DMP

Implementation and improvement of the data management system will be an ongoing process. The practices and procedures identified in this plan will continue to be encouraged broadly within the Network, and in time, we expect them to be widely accepted and adopted by all SIEN park programs.

Chapter 7 DATA ANALYSIS AND REPORTING

Sound data management practices are key components of the SIEN monitoring program, where data will be used by diverse (and sometimes unpredictable) audiences with different requirements and needs—for analysis, interpretation, and reporting to park managers and other interested parties. Therefore, consistent data formats that can be used easily by a broad audience are essential.

This chapter presents an overview of the Network's plans for data analyses, synthesis, and reporting, including a discussion of peer-review of SIEN's overall monitoring program and monitoring goals. The protocols we discuss are those on SIENs "tier-1 implementation list" and include vital signs and protocols whose implementation we will fund in the near-to mid-term and vital sign monitoring efforts which involve collaboration between SIEN and a network park, another NPS program, or other federal or state agency. Detailed descriptions of data analysis will be included in individual monitoring protocols.

The SIEN monitoring program has reporting requirements to ensure that it is meeting its objectives. Consequently, we discuss both SIEN program reporting and analysis goals, and individual protocols, as appropriate.

This chapter will discuss the following categories of reporting and analysis

- Section 7.1: Annual reports
- Section 7.2: Analysis and synthesis reports
- Section 7.3: Protocol review
- Section 7.4: Program review
- Section 7.5: Scientific reports, journal articles, and other professional publications
- Section 7.6: Interpretation and outreach

For many of these report categories we indicate the person who is responsible for the report (the initiator), analyses included, peer review requirements, and due dates. These considerations clarify expectations for these reports and ensure that there is sufficient program accountability, documentation, and evaluation. The relationship between these reports and the larger schedule of network activities is described in Chapter 9.

7.1 Peer Review

As part of the Inventory & Monitoring Program, the National Park Service is committed to promoting the conduct of high quality projects in national parks. An essential element of any science or research program is peer review.

Peer review of SIEN proposals, study plans, monitoring plans, monitoring and sampling protocols (also discussed *infra*, section 7.3), publications, reports, and other products will improve the quality of our scientific research by incorporating the knowledge of other expert scientists and by ensuring that studies conducted can withstand the rigorous scrutiny of other scientists. The credibility of scientific research is enhanced by conveying to other scientists, policy-makers, managers, and the public the knowledge that the work conducted has met accepted standards of rigor and accountability. Effective peer review can help foster research that is fundamentally sound and that increases the broad acceptance of management decisions based on that science.

The National Park Service (WASO office) is in the process of developing Peer Review Guidelines that will apply Service-wide. In the meantime, given the importance of peer review in the development of Network monitoring programs, draft peer review guidelines (for the I&M Program) have been developed.
http://science.nature.nps.gov/im/monitor/docs/DraftPeerReviewGuidelines.doc

7.2 Annual Reports

Annual reports are important 'documented trails' that

- summarize annual data and document monitoring activities for the year
- describe current condition of the resource
- document changes in monitoring protocols
- increase communication within the network and individual parks

Many of our monitoring programs will be active each year, and those programs will generate annual reports each year (Table 7-1). However, some sampling regimes do not require annual activity. For example, some protocols will collect data every 5th year, or even every 10th year (e.g., Landscape Mosaics & Fire Regime). Those programs will produce "annual" reports only when there are significant monitoring activities to document. These reports will be generated using automated data analyses developed for each monitoring project and will address estimates of status, such as means, totals, and proportions. Estimates will be generally design-based or perhaps model-assisted.

Audience: Network staff, park staff including administration, scientists working in parks
Review: Internal network review

Table 7-1. Overview of Vital Signs Monitoring Program Report Production.

Vital Sign	Who initiates?	Peer-review Level	Analyses Performed	Due Date (Fiscal month)
Primary Reporting Responsibility: Inventory & Monitoring Program				
Water Chemistry	Physical Science? Program Lead	Network & NPS-WRD	Annual report: Summary statistics; % below or above pre-established thresholds; others TBD Synthesis report: TBD	TBD
Surface Water Dynamics	Physical Science? Program Lead	Network & NPS-WRD; University and Agency Collaborators	Annual report: Summary statistics; others TBD Synthesis report: TBD	TBD
Weather and Climate	Physical Science? Program Lead	Network; Collaborators (e.g. Western Regional Climate Center)	Annual report: Summary statistics; others TBD Synthesis report: TBD	TBD
Snowpack	TBD	Network; California Cooperative Snow Survey	Annual report: Summary statistics; others TBD Synthesis report: TBD	TBD
Meadow & Wetland Water Dynamics	Meadow Integrity Program Lead	Network	Annual report: Summary statistics; others TBD Synthesis report: TBD	TBD
Selected Plant Communities (Meadows & Wetlands)	Meadow Integrity Program Lead; program leads for each park	Network	Annual report: Summary statistics; others TBD Synthesis report: TBD	TBD
Macro-invertebrates (Meadows)	Meadow Integrity Program Lead	Network	Annual report: Summary statistics; others TBD Synthesis report: TBD	TBD

Vital Sign	Who initiates?	Peer-review Level	Analyses Performed	Due Date (Fiscal month)
Landscape mosaics	Landscape Program Lead; park GIS specialists	Network; Collaborators (e.g. NASA, University)	Annual report: Summary statistics; others TBD Synthesis report: TBD	TBD
Forest dynamics	TBD	USGS-WERC	Annual report: Summary statistics; others TBD Synthesis report: TBD	TBD
Amphibians	Park-based Aquatic Ecologist(s)	Network; USFS & University Collaborators	Annual report: Summary statistics; others TBD Synthesis report: TBD	TBD
Landbirds	Park-based Wildlife Biologist(s)	Network; Not-for-profit & University Collaborators	Annual report: Summary statistics; others TBD Synthesis report: TBD	TBD
Nonnative–Invasive Plants	Park-based Restoration Ecologist (SEKI)	Network	Annual report: Summary statistics; GIS maps; others TBD Synthesis report: TBD	TBD
Primary Reporting Responsibility: Individual Park / Program Responsibility				
Air Quality Ozone Airborne contaminants Atmospheric Deposition Particulate matter Visibility	Network Air Quality Specialist (at SEKI)	Network; NPS-ARD	Annual report: Summary statistics; others TBD Synthesis report: TBD	TBD
Cave–karst physical processes	Network Cave Specialist (at SEKI)	Network; NPS-GRD	Annual report: Summary statistics; others TBD Synthesis report: TBD	TBD
Fire effects on plant communities	Park-based Fire Ecologist(s)	Network; USGS-WERC	Annual report: Summary statistics; others TBD Synthesis report: TBD	TBD
Fire regimes	Park-based Fire Ecologist(s)	Network; USGS-WERC	Annual report: Summary statistics; GIS maps; others TBD Synthesis report: TBD	TBD

7.3 Analysis and Synthesis Reports

The role of analysis and synthesis reports is to

- Examine patterns/trends in condition of resources being monitored
- Discover new characteristics of resources and correlations among resources being monitored
- Analyze data to determine amount of change that can be detected by type and level of sampling
- Provide context, interpret data for the park within a multi-park, regional, or national context
- Recommend changes to management of resources (i.e., feedback for adaptive management)

The purpose of these reports is to provide critical insights into our vital sign status and trends, which can be used to inform resource management efforts and regional resource analyses. This type of analysis will be more in-depth than that conducted for the annual report and will require several seasons (e.g., years) of sampling data. Therefore, these reports will not typically be generated more frequently than every three to five years, for resources sampled annually (e.g., birds). For resources sampled less frequently, or those that intrinsically have a particularly low rate of change (e.g., landscape mosaics, forest stand population dynamics), intervals between reports may be longer. Trend analysis approaches will depend on the number of years of data available. As sample sizes increase, more complex analyses will be possible.

It is noted that special circumstances may escalate individual schedules (e.g., precipitous degradation in vital sign being measured, specific reporting requests). A summary of anticipated SIEN analysis and synthesis reports is provided in Table 7-1. Initial monitoring program review (see section 7.3) may generate the need for supplementary synthesis and analysis.

It is important that results from all monitoring projects within and across all parks be integrated across disciplines in order to interpret changes to park resources as a whole. This will be accomplished by the production of a network-level synthesis report, anticipated to be produced at approximately 10-year intervals.

Audience: superintendents, park resource managers, network staff, and external scientists
Review: external, blind peer-review with at least 3 subject-matter experts, including one statistician

7.4 Protocol Reviews

Purpose of protocol reviews

- Review protocol design and products to determine whether changes are needed
- Part of quality-assurance and peer-review processes

Protocol reviews will be conducted during the monitoring program's first 5-yr Analysis and Synthesis Reporting phase and in conjunction with future Analysis and Synthesis Reports, as needed (minimally at 10-year intervals).

Features of these reviews include

- Outside contractor or academic enlisted to conduct program assessment (e.g., power analyses of data) and report findings.
- Broad spectrum of peers invited to review the Analysis and Synthesis Report, power analysis, and protocol.
- Peers invited to a workshop to discuss the protocol, analyses, whether or not it is meeting project goals, and suggested improvements and changes.
- Program manager or contractor writes a report summarizing workshop, circulates to participants, and posts final report on team web site; sends to NPS regional and WASO program offices.
- Results of the above report are implemented.

Audience: project leads and Network Coordinator
Review: external, blind peer-review with at least three subject-matter experts (including one statistician)

7.5 Program Review

See Chapter 8 for full description of program review processes.

A report to the Network will be part of program review(s), the results of which will be incorporated into the program.

7.6 Scientific Reports, Journal Articles, Professional Publications

This aspect of the program will be directed by program managers (or park staff), and is more at their discretion than previous reporting requirements described in Sections 7.1–7.4. Publishing scientific journal articles or other professional articles is primarily conducted to communicate advances in knowledge, and is an important, widely acknowledged means of quality assurance and quality control, namely through the academic peer-review process. Putting a program's methods, analyses, and conclusions under the scrutiny of a scientific journal's peer-review process is basic to science and one of the best ways to ensure scientific rigor.

Scientific journal articles and other publications (e.g., reports) produced by SIEN efforts will be tracked by the SIEN monitoring program; new publications are part of the Annual Administrative Report and Work Plan (see Annual Reports section), which is sent to the regional and national offices each year. Additionally, reports and scientific publications will be entered into the NatureBib database and available within SIEN's web pages. Principle Investigators of recently conducted (or published) work SIEN network parks frequently make presentations at professional workshops and conferences, and will be invited to present their findings at Science Committee, Board of Director, and park meetings.

Audience: scientific community
Review: peer-review conducted by scientific journal or similar professional

7.7 Interpretation and Outreach

Scientific information gained from monitoring programs usually requires a concerted effort to be translated for the general public. Network staff also speak at trainings for seasonal employees, park staff, and special interest groups (e.g., Yosemite Institute, etc.). Numerous interpretation and outreach opportunities will exist by collaborating with the newly-established Sierra Nevada Research Institute, a partnership between the University of Merced, Network parks, and not-for-profit partners. Staff will continue to share discoveries with the public in written form by contributing articles to natural history newsletters and other interpretive media in the parks. SIEN web pages will serve as a major tool for serving of information (and data).

In the future, the Network plans to produce brochures, fact sheets, and newsletters about the inventory and monitoring program, SIEN vital signs, and the work of our partners.

SIEN's Network Coordinator and program leads are working with the Sierra Nevada Research Institute to develop program to form connections with college students, partners, and the interested public.

Audience: park visitors, partners, and the scientific community
Review: peer-review conducted by network, partner, and park (interpretation) staff

Chapter 8 ADMINISTRATION AND IMPLEMENTATION OF THE SIERRA NEVADA NETWORK MONITORING PROGRAM

This chapter is adapted from the Central Alaska Network's Vital Signs Monitoring Plan (MacCluskie and Oakley 2004)

This chapter describes our plan for administering the SIEN monitoring program. The Network will have a three-year transition period (FY 2008-2010). During this period, the monitoring of nine vital signs (water chemistry, amphibians, weather/climate, landscape mosaics, fire regimes, snowpack, meadow plant communities, wetland water dynamics, meadow invertebrates) will begin as part of four monitoring protocols (lakes, meadow ecological integrity, weather/climate, and landscape dynamics. During the same period, protocol development will continue for the remaining vital signs.

Some vital signs are already being monitored by Network parks, and we will work with park managers to integrate monitoring of existing vital signs into the Network's reporting and information management procedures. In this chapter, we describe the membership of the Board of Directors and Science Committee and the decision-making process of the Network; our staffing plan; how Network operations will be integrated with other park operations, key partnerships, and the periodic review process for the program.

8.1 SIEN Board of Directors, Science Committee, and their Roles in Developing the Monitoring Program

The Board of Directors for the SIEN includes the Superintendent from each park in the Network, the Deputy Superintendents of SEKI and YOSE, the Chiefs of Resources Management for SEKI and YOSE, the Chief Regional Scientist who is split between Sequoia & Kings Canyon National Parks and Pacific West Region, the Pacific West Region Inventory and Monitoring Coordinator, the Pacific West Region Deputy Director liaison for SIEN, and the Network Coordinator as staff to the Board. The Deputy Superintendents from YOSE (Kevin Cann) and SEKI (Russ Wilson) attend most Board meetings and stand in as voting members when their respective Superintendents are unable to attend. One of the local Board members serves as Chair of the Board and this position rotates every two or three years (Table 8-1).

Table 8-1. Composition and voting status of the Board of Directors for the Sierra Nevada Network.

Title	Name	Voting Member	Advisor to Board
Resource Chief YOSE	Niki Nicholas, *Chair*	X	
Superintendent SEKI	Craig Axtell	X	
Superintendent DEPO	Deanna Dulen	X	
Superintendent YOSE	Mike Tollefson	X	
Deputy Superintendent YOSE	Kevin Cann	(alternate)	X
Deputy Superintendent SEKI	Russ Wilson	(alternate)	X
Resource Chief SEKI	Peter Rowlands	X	
Chief Regional Scientist SEKI/PWR	David Graber		X
I&M Coordinator PWR	Penny Latham		X
Deputy Director PWR	Patty Neubacher		X
I&M Coordinator SIEN	Linda Mutch		X

The Science Committee is composed of two Resources Management staff members from both SEKI and YOSE, the SEKI/PWR Science Advisor, one United States Geological Survey representative from both the SEKI and YOSE USGS-Western Ecological Research Center field stations, and four SIEN staff members—Network Coordinator, Data Manager, Ecologist, and Physical Scientist (Table 8-2). SEKI has a formal relationship to provide resources management support to DEPO. As part of that role they also represent DEPO, which has no resources managers, on the Science Committee. The Network Coordinator serves as the Chairperson for the Science Committee.

Table 8-2. Composition of Science Committee for the Sierra Nevada Network.

Title	Name	Park
I&M Coordinator, Chair	Linda Mutch	SIEN
Data Manager	Rose Cook	SIEN
Physical Scientist	Andi Heard	SIEN
Ecologist	Meryl Rose	SIEN
Botanist	Lisa Acree	YOSE
Restoration Ecologist	Athena Demetry	SEKI
Chief Regional Scientist	David Graber	SEKI/PWR
Wildlife Biologist	Steve Thompson	YOSE
Wildlife Ecologist	Harold Werner	SEKI
Research Ecologist	Nate Stephenson	USGS/SEKI
Research Forester	Jan van Wagtendonk	USGS/YOSE

The Board of Directors and the Science Committee work together to accomplish the monitoring program. The Board of Directors is an executive body accountable for the entire program and issues final decisions based on information from the Science Committee. The Science Committee works with the Network Coordinator to make recommendations for all aspects of the program and assists with the work of planning and implementation of monitoring. The Network Coordinator presents the Science Committee's recommendations to the Board of Directors for review, input, and approval.

The Network also uses work groups composed of one or more Science Committee members and other park and USGS staff members to work on protocol development and data management topics of special interest to parks; one of these groups serves as the Data and Information Management Plan steering team. These groups provide an opportunity for those not on the Science Committee to be involved with more focused aspects of monitoring program development. In the future, work groups may be formed to address specific Network issues or to assist with strategies for effectively implementing specific protocols or information management procedures.

Effective program administration requires the Network Coordinator to serve several roles and functions to connect and integrate different parts of the program. One of the most important functions is to facilitate or ensure dissemination of information among the many people and groups involved in the program and ensure full and open communication among participants . This includes the Board of Directors, the members of the Science Committee, the national program, the staff of the Network parks, and cooperators in the program. Communication is accomplished in part by regular meetings of the Science Committee (approximately six per year), the Board of Directors (two or three per year), work groups (as needed), and monthly meetings with the Chair of the Board of Directors and the SEKI Chief of Natural Resources.

The Network Coordinator also sends monthly reports and work plans to the Board. The Coordinator is responsible for managing the Network budget and fiscal planning. The Coordinator works with the Science Committee to establish objectives and priorities for the program. The YOSE and SEKI Resources Management Chiefs and the DEPO Superintendent, along with their staff members, will play an important role in implementing the SIEN program and will set goals and objectives for meeting long-term information needs for the Network parks. Finally, the Network Coordinator must ensure regular and thorough review of the program and, when necessary, correction of program components that are not meeting rigorous standards.

Other SIEN staff members also play important roles in communicating and integrating with park staff. Their efforts include participating in park staff meetings, park workshops, strategic planning meetings, and lecture series, playing lead roles on work groups and in protocol development, developing databases for park projects, and making sure that important park data are documented and made more accessible.

8.2 Staffing Plan

The Network currently has two permanent positions (the Network Coordinator and Data Manager) and three term positions (Ecologist, Physical Scientist, and Administrative Technician). When the Ecologist and Physical Scientist positions end in FY 2008, we plan to hire one of these positions as a Network-funded permanent position, and one as a term position until the transition phase of protocol development is complete. We will then determine whether or not a cost-shared arrangement can be made to share the position with Network parks. We also propose that during this transition phase the hiring of the following term positions: Assistant Data Manager, Data/GIS Technician, and 0.3 FTE Outreach Specialist to be cost-shared with the Interpretative Division in one or more parks. In FY2010, our staffing plan will be re-evaluated to determine the most cost-effective staffing arrangement to sustain the vital signs monitoring program.

Most Network staff play dual roles: program management and protocol design, development, review and implementation. Program administration, management, and communication will be principally, but not exclusively the responsibilities of the Network Coordinator, Data Manager, and Administrative Technician. Other SIEN staff members will are expected to provide program-level support (Table 8-3). Protocol development and implementation is handled by Network staff and park staff, who will work with USGS scientists from the Western Ecological Research Center field stations in Yosemite and Sequoia and Kings Canyon Field Stations and numerous other outside cooperators.

The Sierra Nevada Network has, from the start of the Inventory & Monitoring program, operated under the philosophy that park staff involvement with the program is integral to its success. Park staff involvement ensures that the program is relevant to park information needs. Moreover, the Sierra Network has large parks (658,000 hectares total) with rugged, remote landscapes. Consequently, the costs of implementing a monitoring program will be high. Park base-funded staff contributions, which augment the Network-funded operations, will be essential to implementation of the vital signs protocols. Without contributions from park staff, the Network will have to drop selected protocols or scale back a few protocols to index or sentinel sites that will not be able to provide reliable landscape-scale inference.

The benefits of park staff involvement in implementation of monitoring are substantial, but there are also risks to recognize and address. Park-level needs and priorities change, and although one park superintendent may be able to commit park staff to vital signs monitoring, a subsequent one may be faced with a combination of budget cuts and other urgent priorities that require re-directing staff away from the vital signs program. To mitigate this risk, we identify a core set of protocols that can be managed with predominantly I&M-funded permanent or term staff (2.6 full-time equivalent, or FTE) and approximately 0.8 FTE of park staff (Table 8-4). Additional protocols could be implemented, with an assumption of limited Network contribution (0.8 FTE) and an additional 0.8 FTE of park staff time (Table 8-4). If we lose park involvement in the future, we will still have the flexibility to scale back to our core protocols with Network staff.

We present a staffing plan that shows an optimistic 1.6 FTE of park staff contributions (Table 8-5). The staffing plan has substantial involvement from NPS staff in Sequoia and Kings Canyon National Parks and more limited involvement of staff from Yosemite National Park because of the limited amount of base-funded salaries in the YOSE Resources Management and Science Division. Devils Postpile, which does not have resources management positions, will require Network and SEKI or YOSE staff, along with cooperators to implement monitoring in the monument. Park staff roles vary from providing logistics and data management support to being co-Investigators in protocol implementation.

Table 8-3. Program-level administration, management, and communication, FY 2007- FY 2010. Italicized position titles indicate that review of these park contributions is still needed from Yosemite National Park Board members.

Position	GS Level	Type	Pay Periods to Network/ Year	Affiliation	Role in Vital Signs Program
Network Coordinator	12	Permanent	18	SIEN	Acts as the primary coordinator for all aspects of the monitoring program. Works with the Science Committee to formulate direction and administration of the program. Serves as advisor to the Board of Directors in making programmatic decisions and maintaining accountability of program. Shares program progress and results with diverse audiences, including annual reporting to parks and national program.
Data Manager	11	Permanent	12	SIEN	Is the primary person responsible for all data management for the Network. Establishes and implements the Data Management Plan with assistance from network and park staffs. Works with Outreach Specialist to determine effective design for World Wide Web dissemination of program information. Develops integrated approaches for information synthesis across vital signs protocols. Serves on Science Committee.
Ecologist	11	Term	2	SIEN	Provides protocol-specific information for program-level reports, outreach products, and budget tracking. Communicates about program to diverse audiences. Serves on Science Committee.
Physical Scientist	11	Term	1	SIEN	Provides protocol-specific information for program-level reports, outreach products, and budget tracking. Communicates about program to diverse audiences. Serves on Science Committee.
Administrative Technician	6	Term	26	SIEN	Provides administrative support for all program areas. Does data entry in NatureBib and Wildlife Observations databases and maintains project tracking and budget databases for program accountability.
Outreach Specialist	7/9	Term	10	YOSE or SEKI	Develops content for and assists with design for web pages, brochure, and newsletters. Develops executive briefs on network vital signs and inventory products. Cost-shared position with park(s).
Assistant Data Manager	7/9	Term	4	SIEN	Handles technical aspects related to delivery/communication of monitoring program information via the web. Assists with implementation of Data Management Plan. Oversees data mining and documentation needs.
GIS Coordinator	12	Permanent	3	SEKI	Works with Data Manager t Data Management to implement Plan.
YOSE Contact-TBD	?	?	?	YOSE	Works with Data Manager to implement Data Management Plan.

Table 8-4. Estimated Network and park contributions to fully implement new protocols by FY2011. By 2011, Network permanent and term staffing are reduced from the level in the FY2007-2010 transition period (see Table 8-3 and Table **8-5**) when protocols are in development or in early stages of implementation. This reduction is to accommodate the flexible spending needs of protocol implementation (seasonals, partnerships, equipment, travel, etc.) and to reduce fixed costs. The upper portion of the table shows the "core" new protocols the Network would implement with Network staff and an assumed 0.8 FTE of park staff support. The lower portion of the table shows additional protocols that will require more park staff support in order to implement. Numbers in columns indicate the number of pay periods dedicated by permanent or term staff to implement each protocol. Not included are the Network staff pay periods that go toward overall program coordination, management, outreach, and administrative reporting, or seasonal staffing.

Protocol	Coordinator	Data Manager	Ecologist	Physical Scientist (.7 FTE - shared)	Data Technician or Asst. Data Manager	Park Staff	Total Pay Periods
Core Protocols that the Network Commits to Implement with or without Park Staff Contributions							
Weather/Climate		2		2	3	2	**10**
Lakes		2	4	13	3	2	**24**
Meadow Ecological Integrity	2	2	5		4	10	**23**
Landscape Dynamics	2	2	2		3	4	**13**
*Birds		1	10		3	2	**16**
Subtotal pay periods	**4**	**11**	**21**	**15**	**16**	**20**	**86**
Protocols that Need Park Staff Contributions to Implement							
*Forest Dynamics	4	1			2	8	**15**
*Streams & Rivers		1		3	3	8	**14**
*Non-native Plants		1	3		3	5	**12**
Subtotal pay periods	**4**	**3**	**3**	**3**	**8**	**21**	**41**
Total pay periods and FTEs	**8 =.3 FTE**	**14 =.5 FTE**	**24 =.9 FTE**	**18 =.7 FTE**	**24 =.9 FTE**	**41 1.6 FTE**	**127 =4.8 FTE**

* At a SIEN Board of Directors meeting on December 5, 2006, the Board indicated that they wanted forest dynamics and streams & rivers protocols to be given higher priority for implementation than birds and non-native plants. The Network staff and Science Committee will need to evaluate if anticipated SIEN staffing levels and park staff contributions can accommodate these priorities.

Table 8-5. Protocol-level roles and responsibilities, FY2007-FY2010. Italicized position titles and pay periods with question marks indicate that review of these park contributions is still needed from Yosemite National Park Board members.

Position	GS Level	Type	Pay Periods to Network/ Year	Affiliation	Role in Protocol Development and Implementation
Network Coordinator	12	Permanent	8	SIEN	Ensures that timelines are adhered to and that budgets are realistic in development phase (all protocols). Facilitates communication and contracts/agreements among park and outside collaborators. Serves as co-Investigator on one protocol. Works with other SIEN and park staff to integrate park-collected datasets with vital signs the Network implements.
Data Manager	11	Permanent	13	SIEN	Oversees database design and development for all protocols. Works closely with protocol Principal Investigators (PIs) and Assistant Data Manager to develop data management plans for each protocol—including establishing flow and oversight of data from collection to analysis, reporting, and archiving. Responsible for the certification and dissemination of quality controlled data. Responsible with other SIEN staff for the integration of appropriate park datasets with vital signs the Network implements.
Ecologist	11	Term	24	SIEN	Oversees the development and implementation of amphibian portion of the lakes protocol and the bird protocol. Serves as Principal Investigator on these protocols and is responsible for the logistics, staffing, fieldwork, data entry, quality assurance/quality control, and analysis and reporting for these protocols. Will assist YOSE staff with implementation of the meadow ecological integrity protocol, working closely with SEKI Co- Investigators.
Physical Scientist	11	Term	24	SIEN	Serves as PI on lakes protocol, streams and rivers protocol, and is Network contact developing weather/climate protocol with collaborators. Responsible for the logistics, staffing, fieldwork, data entry, quality assurance/quality control, and, analysis and reporting for these protocols. Works with Data Manager and Park staff to implement weather/climate protocol and to assist with integration of park air quality monitoring data into the Network's data management, analysis and reporting systems.
Assistant Data Manager	9	Term	22	SIEN	Provides support with database design and programming as needed. Assists with writing and implementing data management guidelines and SOPs associated with protocols. Assists with data entry and processing where needed. Assists with implementation of Data Management Plan.

Position	GS Level	Type	Pay Periods to Network/ Year	Affiliation	Role in Protocol Development and Implementation
Data/GIS Technician	6/7	Term	26	SIEN	Documents, digitizes, and organizes existing legacy datasets and provides data management and GIS support to protocol PIs for collection, processing, analysis and reporting.
Plant Ecologist	11	Permanent	8	SEKI	Responsible for the implementation of plant communities portion of meadow protocol for SEKI and DEPO, as well as ensuring that the collation and summary of meadow vegetation data are completed for all SIEN parks. Assists SIEN staff with the analysis and reporting of this vital sign.
Wildlife Ecologist	12	Permanent	5	SEKI	Provides support for the meadow invertebrates and wetland water dynamics vital signs as part of the meadow protocol in SEKI and DEPO (logistics, training, data compilation). Park contact for birds protocol.
Botanist	11	Permanent subject to furlough	3?	YOSE	Provides logistical and field training support to implement the meadow protocol in Yosemite. Works closely with SIEN Ecologist and SEKI Co-Investigators to ensure data quality standards are met for all parks.
Wildlife Biologist	12	Permanent	2?	YOSE	Provides logistical support to facilitate implementation of birds and lakes monitoring protocols in Yosemite.
Aquatic Ecologist	11	Permanent	6	SEKI	Serves as co-Investigator on lakes and streams & rivers protocols. Works with Physical Scientist to handle logistics, crew hiring and training, field data collection and data compilation and summary for SEKI and DEPO.
Physical Scientist	11	Term	1?	YOSE	Park contact for streams & rivers protocol to assist with logistics and integration with other YOSE water chemistry monitoring.
GIS Coordinator	12	Permanent	4	SEKI	Provides support to Data Manager to assist with implementation of Data Management Plan in SEKI and DEPO. Works with SIEN staff and YOSE Landscape Ecologist to manage remote-sensing imagery.
Fire GIS Specialist	11	Permanent	2	SEKI	Assists with integration of annual SEKI fire GIS data layers into SIEN landscape dynamics monitoring protocol.
Fire GIS Specialist	11	Term subject to furlough	1?	YOSE	Assists with integration of annual YOSE fire GIS data layers into SIEN landscape dynamics monitoring protocol.
Landscape Ecologist	9/11	Permanent subject to furlough	3?	YOSE	Serves as co- Investigator with an outside cooperator on landscape dynamics protocol. Works with Network Coordinator and Data Manager to manage task agreements for processing and interpreting remote-sensing imagery. Assists with analysis and reporting for SIEN landscape dynamics.

Position	GS Level	Type	Pay Periods to Network/ Year	Affiliation	Role in Protocol Development and Implementation
Air Quality Specialist	12	Permanent	2	SEKI	Works with SIEN staff to integrate SEKI air quality and weather data into SIEN information management and reporting systems. Assists with logistics for streams & rivers protocol.
Air Quality Specialist	11?	Permanent subject to furlough	1?	YOSE	Works with SIEN staff to integrate YOSE air quality and weather data into SIEN information management and reporting systems.
Restoration Ecologist	11	Permanent subject to furlough	3	SEKI	Oversees protocol development – early detection SOPs for invasive plants early detection protocol; prioritization and updates to invasive plant lists.
Botst	11	Term subject to furlough	1?	YOSE	Assists SEKI Restoration Ecologist with early detection SOPs for invasive plants protocol, and prioritization and updates to invasive plant lists.

8.3 Integration of Program with Park Operations

Implementing long-term monitoring in SIEN parks will require collaboration and cooperation with multiple park divisions and programs. As discussed above, we have long had participation from our natural resources management programs and USGS field stations in both the inventory and planning phases for long-term monitoring. Some participation will continue into the implementation of vital signs monitoring, as some park biologists, physical scientists, and GIS specialists will continue to play important roles in protocol development and implementation.

Another key area of integration will be with our Parks' Divisions of Interpretation. The Outreach Specialist we plan to hire in FY 2007 will meet with Interpretive Divisions of the parks and with the Superintendent of Devils Postpile to identify ways to share with broader audiences information gained from vital signs monitoring—especially all park staff and the public. In addition to using World Wide Web Inter- and Intra-net sites, newsletters, and a brochure to share information with large audiences, we would like to directly approach park visitors through interpretive programs and outreach to local schools. The Interpretive Divisions also have expertise in sharing park natural resources information with the media, and could advise and assist us in sharing our stories with local media. We would like to work with the Interpretive Divisions to develop a Communication and Outreach Plan that outlines strategies for communicating vital signs monitoring results to diverse audiences.

Our parks are predominantly designated Wilderness lands. Any request to install permanent monitoring equipment such as groundwater monitoring wells, stream gauging stations, or meteorological stations will require extensive communication about the benefits of doing such monitoring in Wilderness and a minimal tool analysis to demonstrate that what we propose is the least invasive means of getting the information we need. Wilderness Coordinators from the Divisions of Fire and Visitor Management in our large parks have been involved with some of our planning meetings, but this year it will be a priority to improve our communication with Wilderness staff and our Board of Directors on these important Wilderness concerns, so that common resolutions and decisions can be made across the Network parks.

There will be numerous logistical issues to resolve involving the hiring, housing, and supervising of field crews implementing the protocols. For field crews to sample sites in remote areas, we will need to work closely with Park staff involved with stock and helicopter management, and research and backcountry permitting. This includes the Divisions of Natural Resources, Maintenance, and Fire and Visitor Management. We will also work closely with parks and local Park Safety Officers to participate in safety programs and training–including backcountry communication procedures, helicopter safety, first aid, and development of job hazard analyses for each vital signs protocol. Park housing will be important for some crews, and this will require early communication with park administrative and maintenance staff who manage housing and other park divisions that compete each year for available housing slots.

As part of the protocol development process, it will be important for Network and park protocol leads and participants to identify areas of integration with park operations and programs that will be needed for the protocol to be effectively implemented.

8.4 Partnerships

The Sierra Nevada Network has numerous current or planned partnerships for the development of vital signs monitoring protocols. Some of these partnerships may be continued in the implementation of a few vital signs protocols, and other protocols will be implemented entirely with "in-house" Network and park staff. As the program develops further, we expect to implement protocols and develop outreach and communication products with additional partners who will assist us. The partnerships summarized in Table 8-6 are currently assisting us with development of some portion of our monitoring program, and a couple are noted as "planned" agreements.

Several USGS Biological Resources Division scientists who are associated with the Western Ecological Research Center Sequoia & Kings Canyon and Yosemite Field Stations have participated in protocol development work groups at no cost to the Network. Other scientists from the Scripps Institution of Oceanography and the State Department of Water Resources/Cooperative Snow Surveys have donated time and equipment to begin meteorological monitoring at Devils Postpile National Monument. A partnership that we will develop further this year will be with the UC Merced Sierra Nevada Research Institute, which has recently established a field station in Yosemite National Park. This institute could be a source of student assistance for the monitoring program, library resources to our parks, which are located remotely from universities, and academic expertise in resources we will monitor (e.g., surface water dynamics, snowpack, wetlands).

Table 8-6. Partnerships for the Sierra Nevada Network monitoring program.

Partner	Type of Relationship	Work Accomplished
US Geological Survey, Biological Resources Division	In-kind services	• Participate in meadow ecological integrity, forest dynamics, non-native plants, and landscape dynamics protocol work groups and Network Science Committee.
University of California, Riverside	Cooperative Agreement (CESU)	• Assist with water chemistry/surface water dynamics protocol development for lakes.
Colorado State University, Ft. Collins	Cooperative Agreement (CESU)	• Develop meadow ecological integrity (vegetation communities, wetland water dynamics) protocol with SIEN meadow work group and Rocky Mountain Network.
UC White Mountain Research Station	Cooperative Agreement (CESU)	• Develop meadow invertebrates monitoring protocol with SIEN meadow work group and CSU-Ft. Collins.
The Institute for Bird Populations	Contract	• Develop bird monitoring protocol with SIEN bird work group and statistician(s).
Western Regional Climate Center/Desert Research Institute	Cooperative Agreement (CESU)	• Assess current climate monitoring in SIEN parks, provide analyses, and make recommendations for SIEN climate monitoring protocol.
Scripps Institution of Oceanography and California Dept. of Water Resources	In-kind services	• Donation of time and equipment to establishment of DEPO meteorological monitoring station and SOP.
University of Colorado-Boulder	Cooperative Agreement (CESU)	• Develop methods to narrow the search frame within burned areas to efficiently detect target non-native plants after fire.
NASA-AMES	In-kind services	• Advising on imagery and technology for addressing landscape dynamics protocol objectives.
US Forest Service	In-kind services	• Sharing peer-reviewed protocol for amphibian monitoring; advising on amphibian monitoring sites and approaches. • Sharing approaches to monitoring landscape change in Sierra Nevada. • May seek information from USFS Forest Inventory & Assessment and Forest Health Monitoring program for Forest Dynamics monitoring work group.
University of Idaho-Moscow	Cooperative Agreement (CESU)	• Provide statistical support to protocols and monitoring plan. • Provide additional monitoring plan support.
UC Santa Barbara	Cooperative Agreement (CESU) - planned	• Assist SIEN staff and protocol work group with landscape dynamics protocol development.
UC Merced Sierra Nevada Research Institute	Cooperative Agreement (CESU) – planned	• To be determined

8.5 Review Process for the Program

A long-term monitoring program must schedule periodic evaluation and review to determine if monitoring objectives are being met, and if staffing and management of the program are cost-effective. The Network must also ensure that the monitoring information is accessible to park managers and other audiences. We summarize a variety of review mechanisms to evaluate different aspects of the program (Table 8-7).

Table 8-7. Review Mechanisms for the SIEN monitoring program.

Review	Timing	Who is Involved	Intent of Review
Staffing Plan	FY 2010	Board of Directors and Science Committee	Review existing staffing plan for network and recommend any changes needed to fully implement monitoring.
Annual Administrative Report and Work Plan	Annual	Board of Directors and Science Committee	Provide yearly accountability for program. Report on accomplishments and explain goals and projects for the next fiscal year.
Report to the Science Committee (included protocol review discussed in chapter 7)	Bi-annual to 5-year	All parties that collect data for the network, other invited experts, Science Committee, Board of Directors, representatives from Park Divisions.	Provide technical details on results and status of all data collection within the program. Evaluate if program goals and objectives are being met, how well the program is integrated with other related park monitoring efforts, and if the information is effectively reaching intended audiences.
10-year Program Review	Decadal	All parties that collect data for the network, other invited experts, Science Committee, Board of Directors, representatives from Park Divisions.	Provide synthesis of data collected by program, evaluate the utility to park management, evaluate administration/operations of program, make recommendations for all aspects of program.

We use the Annual Administrative Report and Work Plan (AARWP) to provide the Science Committee, the Board of Directors, and other Park staff with an opportunity to review what has taken place in the past year and what is planned for the next year. It is important that we take the time each year to recognize successes as well as to identify areas in need of improvement, and what steps should be taken to make the required changes.

By the end of FY 2010, we will evaluate our existing staffing plan, and with the added information from more fully developed protocols as well as park-level capacity to contribute to the program, we will modify the staffing plan to best meet the needs of the Network. This includes Network staffing levels, duty stations and roles & responsibilities with program management and protocol implementation, as well as finalizing park staff roles and responsibilities in the program.

Another level of review for the program will be a biannual to 5-year Report to the Science Committee. The needed frequency for this review will likely vary over time: it is likely that more frequent reviews (biannual) will be needed early in the program, and less frequent (5-year) may suffice after the protocols are well-established. This will be a two-day symposium where all park staff and cooperators working within the program will present the results and status of the work they are conducting. Outside participants (academic, USGS, others) will be invited to provide expertise in specific subject areas of the protocols. The second day of the meeting will be for the Science Committee only. They will discuss the presentations of the previous day and evaluate the merit of the work scientifically and operationally. The specific protocol reviews discussed in chapter 7 will be part of this 5-year review. The findings and decisions made during this review will be documented and presented to the Board of Directors for their endorsement. This format is based on a review process used by some National Science Foundation Long-term Ecological Research sites (MacCluskie and Oakley 2004). The first report to the Science Committee will be held by May 2008.

Our third level of review will be a ten-year program review. The ten-year review will focus on presentations and discussions that link quantitative analyses of the data to resource management and interpretive applications. The Network Coordinator will initiate the Network Monitoring Program review. The goal of these reviews is to have the program evaluated by highly qualified professionals. Actions of the program review include

- Program manager/network team summarizes program and activity to date including summary of results and outcomes of 5-year protocol reviews.
- Invitees discuss the program, whether it is meeting program goals, and possible improvements.
- Program manager develops strategy with SIEN Science Committee on which recommendations to implement, then how and when they will be implemented.

Typical topics addressed will be a general review of our program efficacy, accountability, scientific rigor, contribution to adaptive park management and larger scientific endeavors, outreach, partnerships, and products. Program reviews will cover monitoring results over a longer period of time, including program structure and function, to determine whether the program is achieving its objectives, and whether those objectives are still relevant, realistic, and sufficient.

Audience: superintendents, resource managers, network staff, NPS Monitoring Program managers, and external scientists
Review: external, blind peer-review with at least 5 subject-matter experts including one statistician and one monitoring program manager

Chapter 9 SCHEDULE

Parts of this chapter were adapted from the San Francisco Bay Area Network Monitoring Plan (Adams et al. 2004).

This chapter describes the schedule that the Network will follow during the next four years to develop monitoring protocols and implement the Vital Signs Monitoring Plan.

9.1 Protocol Development

The Network is developing eight protocols over the next four years. The following protocol development schedule indicates when we will complete protocols and submit them for peer-review (Table 9-1). Protocol development start and completion dates are staggered to manage staff work loads. The start date indicates when significant resources are first channeled into the direct development and writing of a protocol. For all protocols, including those scheduled to start in FY07-08, work groups have met and discussed monitoring objectives and approaches.

For several of the protocols scheduled to start in FY07-08, we have initiated preliminary projects that will inform protocol development. For example, we have started a CESU agreement with the Western Regional Climate Center to assess current climate monitoring in the Sierra Nevada Network and to recommend how the Network can best allocate resources to enhance existing climate monitoring. This information will be used to guide the direction and development of the Weather and Climate monitoring protocol.

All protocols are scheduled to be implemented by FY 2010. However, at the December 5, 2006 Board of Directors meeting, Board members expressed concern that there were not enough resources to implement all eight protocols. The Board's recommendation to the SIEN staff and Science Committee was to move forward more quickly on protocols the Board identified as having the highest priority, and to decelerate lower priority protocols. We expect that we will have at least two protocols that will need to await additional resources or be reduced in scope before being implemented.

9.2 Monitoring Timing and Frequency

The Network's annual monitoring schedule depicts the frequency and month(s) of the year that we will be sampling for each vital sign (Table 9-2). Frequency of sampling will range from continuous (i.e., automated collection at weather and stream gauging stations) to once every few years. Many protocols will have several collection frequencies. For example, sampling at index sites will be more frequent than survey sites. We anticipate that much of our sampling will occur during the spring, summer, and fall months--although these details still need to be determined.

Table 9-1. Protocol Development Schedule ('D' is developing a protocol; 'I' is implementing a protocol).*

Protocol	FY06	FY07	FY08	FY09	FY10	Target date for protocol review
Lakes	D	D	I	I	I	October 2007
Landbirds	-	D	D	-	-	January 2008
Landscape Dynamics	-	D	D	I	I	February 2008
Weather and Climate	-	-	D	D	I	October 2008
Meadow Ecological Integrity	D	D	D	D/I	I	December 2008
Rivers and Streams	-	-	D	D	I	April 2009
Early Detection of Non-native Plants	-	D	D	D/I	I	May 2009
Forest Dynamics	-	D	D	D	I	June 2009

*At a December 5, 2006 Board of Directors meeting, the Board members indicated that their priorities for protocol development and implementation are as follows: 1) highest priority—landscape dynamics, meadow ecological integrity, and forest dynamics; 2) high priority—lakes, streams & rivers, weather & climate; 3) lower priority—birds and non-native plants. Based on these priorities, the SIEN staff and Science Committee will evaluate the timeline, available resources and expertise, and the proposed budget (chapter 10), and communicate to the Board revised budget and schedule alternatives associated with this prioritization, including the consequences for the timing of protocol implementation. Thus the schedule presented above will need to be revised, as feasible, for the final Phase III to reflect the Board's recent prioritization. Communication with the Science Committee and protocol work group leads will be needed before any changes can be made.

Table 9-2. Frequency and timing of vital signs monitoring (Most of this information is still 'to be determined'—indicated by 'TBD' or gray shading—this table will be more complete by Sept. 2007)

Vital Sign	Sampling Frequency	January	February	March	April	May	June	July	August	September	October	November	December
Amphibians	Annually												
Fire regimes	TBD												
Forest dynamics	TBD												
Non-native plants	TBD												
Landbirds	Annually					X	X	X	X	X			
Landscape mosaics	TBD												
Macro-invertebrates (meadows)	Annually						X	X	X	X			
Selected plant communities (meadows)	Annually						X	X	X	X			
Snowpack	Continuous and more TBD												
Surface water dynamics	Continuous and more TBD	X	X	X	X	X	X	X	X	X	X	X	X
Water chemistry	Annually												
Weather and climate	Continuous	X	X	X	X	X	X	X	X	X	X	X	X
Wetland water dynamics (meadows)	Index: Continuous; Survey: Annually						X	X	X	X			

Chapter 10 BUDGET

This chapter is adapted from the Central Alaska Network's Vital Signs Monitoring Plan (MacCluskie and Oakley 2004).

In this chapter we present the budget for the SIEN monitoring program during the first year of operation after review/approval of our plan (2008), and we show an estimated five-year projected budget. We first show a simplified Network budget using the same expense categories networks use in preparing the Annual Administrative Report and Work Plans that are submitted to Congress (Table 10-1). In Table 10-2, we show the same budget but with more detail, including our estimations for Network resources devoted to information and data management. Finally, we show a five-year projected budget that shows protocol budgets inclusive of seasonal staffing, operations/equipment, and travel costs associated with each protocol (Table 10-3).

The SIEN receives $657,900 from the National Park Service Servicewide Inventory & Monitoring Vital Signs program and $61,500 from the NPS Water Resources Division annually. During the first year of monitoring program implementation (2008), we will also still be developing most of our protocols. We consider the years 2008-2010 "transition years" in which we will have more Network staffing to complete protocol development as well as Data Management Plan implementation. During 2008-2010, we anticipate allocating 65% of the budget to core network Personnel, while this amount is reduced to about 55% by 2011-2012 after protocols are expected to be developed and in implementation. In 2008, 35% of our overall budget is allocated to data/information management; this figure incorporates an actual allocation of 47% of personnel funding dedicated to personnel for information/data management. The reduced core staffing by 2011-2012 accommodates the additional seasonal staffing needed for protocol implementation. We also anticipate substantial involvement from park staff in implementing some protocols (see Chapter 8).

To complete protocol development, the network anticipates continued Cooperative Agreements via Cooperative Ecosystem Studies Units or other entities. Aspects of some protocols (landscape dynamics, birds, climate/weather) may require Cooperative Agreements to continue for protocol implementation. Through 2008-2010, we expect to allocate at least 25% of the budget annually to Cooperative Agreements or Contracts: by 2011-2012, this amount is likely to decrease to 10% to 15%, when more protocols are implemented using network and park staff.

We made every effort not to underestimate travel and operations/equipment needs for 2008-2010, but changes and discrepancies may present themselves. We expect these costs to be part of the protocol implementation budgets shown in Table 10-3. As protocols are further developed, we may find funding shortfalls to meet current objectives of park- or network-level inference for some vital signs. As discussed in sample design costs and benefits (Chapter 4), access to remote sites will be costly for the Network's three large parks. It is possible that, in addition to the climate monitoring protocol, other protocols may need to scale back to monitoring more "accessible" sites, which in turn would not provide network-level inference.

Table 10-1. Anticipated budget for the SIEN Vital Signs Monitoring Program in the first year of implementation after review and approval of the monitoring plan.

	SIEN Vital Signs Monitoring Budget		2008	
Income				
	Vital Signs Monitoring		$657,900	
	Water Resources Division		$61,500	
		Subtotal	**$719,400**	
Expenditures				**% by budget category**
	Personnel - core staff		$454,000	69%
	Personnel - seasonal staff		$38,000	6%
	Cooperative Agreements		$160,900	24%
	Contracts		$20,000	3%
	Operations/Equipment		$23,000	3%
	Travel		$20,000	3%
	Other		$3,500	1%
		Subtotal	$719,400	

Guidelines for developing a monitoring program suggest that approximately 30% of the overall budget should be allocated to information/data management so that information is not lost and adequate communication of monitoring results occurs. In Table 10-2, we provide the percent of time that each Network position is expected to devote to information/data management. These projections of time do not reflect the time spent on information/data management by park staff who are not paid for by the Network. Our estimate of 35% allocation of funds, overall, to information/data management may be underestimated; these projections of time do not reflect the time spent on information/data management by those park staff not paid for using Network funds.

Network (and park) staff time devoted to information/data management will need to be clearly defined in work plans and performance plans, so that the responsibilities are understood and there is accountability for performing them. Further, the Network is expected to reduce data management staffing by 2011 (Table 10-3); thus, other staff will need to increase their data/information management roles at that time.

The budget will be more certain after protocols are further developed and costs associated with protocols can be more accurately estimated. In 2010, we will review our staffing plan and budget, and make any needed adjustments for implementation of all the protocols that the budget can support. The budgetary challenge of a long-term monitoring program will be in balancing fixed-costs (permanent staff and operational expenses) needed to sustain the program and to provide consistency and longevity, with flexible spending needs (seasonals, cooperative agreements/contracts, travel, supplies, training). Program support from permanent park staff will also be important in providing depth and continuity to the program, by assisting with implementing some vital signs. Network staff will not be sufficient to meet all of the program's needs in implementation of all protocols and in managing the data and information from the program.

Table 10-2. Detailed budget for the SIEN Vital Signs Monitoring Program in the first year of implementation after review and approval of the monitoring plan.*

	SIEN Vital Signs Monitoring Budget		2008		
Income					
	Vital Signs Monitoring		$657,900		
	Water Resources Division		$61,500		
		Subtotal	**$719,400**		
Expenditures					
Core Network Personnel		*GS-level*		*Information Management*	
	Network Coordinator	12	$93,000	5%	$4,650
	Data Manager	11	$75,000	100%	$75,000
	Ecologist (Term)	11	$71,000	15%	$10,650
	Physical Scientist (Term-Furlough)	11	$69,000	15%	$10,350
	Administrative Technician (Term-75%)	6	$30,000	15%	$4,500
	Assistant Data Manager (Term)	9	$61,000	100%	$61,000
	Data/GIS Technician (Term-furlough)	6	$40,000	100%	$40,000
	Outreach Specialist (Term-25%, shared)	9	$15,000	40%	$6,000
	Subtotal Core Staff		**$454,000**	**47%**	**$212,150**
Seasonal Personnel (estimated)					
	Lakes monitoring				
	3 seasonals/ 7 pay periods	5	$27,000	30%	$8,100
	1 seasonal/7 pay periods	7	$11,000	30%	$3,300
	Subtotal Seasonal Staff		**$38,000**		**$11,400**
	Subtotal All Staff		**$492,000**		**$223,550**
Cooperative Agreements					
	Meadow monitoring- protocol development				
	•vegetation and water (CESU agreement)		$31,500		
	•macroinvertebrates (CESU agreement)		$43,400		
	Climate monitoring protocol development				
	•CESU agreement		$20,000	30%	$6,000
	**Bird monitoring protocol testing*				
	•CESU agreement		*$40,000*	*30%*	*$12,000*
	Statistician support to protocols				
	•CESU agreement (University of Idaho)		$26,000	30%	$7,800
	Subtotal		**$160,900**		**$25,800**
Contracts					
	**Non-native plants or Forest Dynamics protocol development*		*$20,000*		
	Subtotal		**$20,000**		
Operations/Equipment					
	Lake protocol		$6,000		
	Core network staff and functions		$17,000		
	Subtotal		**$23,000**		

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Travel					
	Protocol development and implementation		$4,000		
	Core network staff		$16,000		
		Subtotal	**$20,000**		
Other					
	Miscellaneous		$3,500		
		Subtotal	**$3,500**		
		Total	**$719,400**	**35%**	**$249,350**

*At a December 5, 2006 Board of Directors meeting, the Board members indicated that their priorities for protocol development and implementation are as follows: 1) highest priority—landscape dynamics, meadow ecological integrity, and forest dynamics; 2) high priority—lakes, streams & rivers, weather & climate; 3) lower priority—birds and non-native plants. Based on these priorities, the SIEN staff and Science Committee will evaluate the timeline, available resources and expertise, and the proposed budget, and communicate to the Board revised budget and schedule alternatives associated with this prioritization, including the consequences for the timing of protocol implementation. Thus the protocol development priorities in the budget presented above will need to be revised (as feasible) for the final Phase III to reflect the Board's recent prioritization. Communication with the Science Committee and protocol work group leads will be needed before any changes can be made.

Table 10-3. Estimated 5-year projected budget for the SIEN Vital Signs Monitoring Program. Personnel costs conservatively assume 30% benefits, and increases between years include a 3% cost of living increase per year. This budget also applies a 0.4% base increase per year (reflected in last line on table). Protocol budgets include estimated costs of seasonal staff, travel, and operations/ equipment associated with SIEN protocols.

Sierra Nevada Network Projected Budget	Transition Period			Full Implementation	
Core Personnel	**2008**	**2009**	**2010**	**2011**	**2012**
Network Coordinator	93,000	95,790	98,664	101,624	104,672
Data Manager	75,000	77,250	79,568	81,955	84,413
Ecologist (Term)	71,000	73,130	75,324		
Physical Scientist (Term-Furlough)	69,000	71,070	73,202		
Administrative Technician (Term-75%)	30,000	30,900	31,827		
Assistant Data Manager (Term)	61,000	62,830	64,715		
Data/GIS Technician (Term-furlough)	40,000	41,200	42,436		
Outreach Specialist (Term-25%, shared)	15,000	15,450	15,914		
Ecologist (Permanent)				76,800	79,104
Physical Scientist (70%, shared)				54,309	55,938
Admin Technician (Perm-50%, shared)				23,300	23,999
Data/GIS Technician (Perm-furlough)				50,000	51,500
Subtotal	**$454,000**	**$467,620**	**$481,649**	**$387,987**	**$399,626**
Core Staff Travel	**$16,000**	**$15,000**	**$15,000**	**$18,000**	**$18,360**
Core Operations/Equipment	**$17,000**	**$15,300**	**$15,000**	**$20,000**	**$20,400**
***Protocol Development & Implementation**					
Lakes	46,000	60,000	61,800	63,654	65,564
*Birds	42,400	50,000	51,500	53,045	54,636
Climate	20,000	15,000	15,450	20,000	20,600
Meadows	75,000	77,250	79,568	81,955	84,413
*Non-native plants	20,000	20,000		requires park staff	
Landscape dynamics			5,000	35,000	36,050
*Streams & Rivers	requires park staff to fully implement			26,000	26,780
*Forest dynamics (develop in-house)				requires park staff	
Statistician support	26,000	26,780	27,583	20,000	
Subtotal	**$229,400**	**$222,250**	**$213,318**	**$299,654**	**$288,043**
Other (miscellaneous)	3,000	2108	201	2,427	4,550
Total	$719,400	$722,278	$725,167	$728,067	$730,979

*At a December 5, 2006 Board of Directors meeting, the Board communicated their priorities for protocol implementation to the Network Coordinator. The bird, forest dynamics and non-native plant protocol budgets will need to be re-considered, *and if feasible*, funds shifted to reflect the higher emphasis on forest dynamics and streams/rivers, and lower emphasis on birds and non-native plants. Communication with the Science Committee and protocol work group leads will be needed before any changes can be made.

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